U.S. Department
of Transportation

**United States
Coast Guard**

Aids to Navigation

Visual Signal

Design Manual

COMDTINST M16510.2A

U.S. Department
of Transportation

**United States
Coast Guard**

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Subj: AIDS TO NAVIGATION VISUAL SIGNAL DESIGN MANUAL

1. PURPOSE. This Manual discusses the theory of visual signaling, as it pertains to marine lighted aids to navigation, establishes step-by-step procedures for the selection and evaluation of signaling hardware, forwards the Allard's Law Computer Program, for automated evaluation of signaling hardware, and provides tabulated photometric data on Coast Guard optical systems used for lighted aids to navigation.

2. ACTION. Area and District Commanders, Commanders of Maintenance and Logistics Commands, Commanding Officers of Civil Engineering Units, Commanding Officers of Headquarters Units, Assistant Commandants for Directorates, Chief Counsel, and Special Staff Offices at Headquarters shall ensure that the provisions and guidance of this Manual on visual signal design are followed.

3. DIRECTIVES AFFECTED. Luminous Intensities of Aids to Navigation Lights, COMDTINST M16510.2, is canceled.

4. MAJOR CHANGES. This Manual replaces the Luminous Intensities of Aids to Navigation Lights Manual, and provides a more thorough discussion of the theory of visual signaling. The tabulated photometric data have been updated to reflect current standard optics and lamps. In addition, the new Allard's Law Computer Program provides an automated means to evaluate the effectiveness of selected signaling hardware.

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CHAPTER 1. INTRODUCTION

A. Purpose. Coast Guard personnel use information from a series of documents to select optical systems for lighted aids to navigation. This manual collects and collates into one reference the latest scientific theory and methods involved with the generation of visual light signals, the transmission of these signals through the atmosphere, and the detection of these signals by mariners. This manual:

- Discusses the theory of visual signaling;
- Explains how to select optics for lighted aids to navigation;
- Explains how to evaluate the performance of existing optical systems;
- Explains methods of calculating effective intensity; and
- Provides example calculations to demonstrate the processes discussed.

B. Background. In 1970, the Ocean Engineering Division of Coast Guard Headquarters published a visual signaling manual detailing relevant theory pertaining to Coast Guard visual aids to navigation. Since that time, there have been many changes in visual signaling equipment. In addition, a number of studies and tests have been conducted to provide new information on the performance of Coast Guard aid-to-navigation lights. A list of published information can be found in the bibliography of this document.

C. Format and Content.

1. Chapter 1 provides the purpose, background, and format of this document.

2. Chapter 2 discusses the theory of visual signaling. It explains how a light signal is generated, how the signal is affected by the atmosphere, and describes factors affecting detection by the mariner. A basic understanding of the material in Chapter 2 is required to evaluate the performance of Coast Guard aid-to-navigation lights.

3. Chapter 3 presents detailed procedures for selecting optical systems for lighted aids to navigation. It discusses general considerations for selecting optical systems and provides step-by-step procedures to select optics for buoys, minor aids, major aids, and range lights.

4. Chapter 4 describes the Allard's Law Computer Program, used for automated determination of luminous intensity requirements for visual signals and/or evaluation of the effectiveness of specific optics to meet operational requirements.

5. Chapters 5 through 8 summarize technical information for standard Coast Guard aids-to-navigation signaling hardware. The luminous intensities listed in Chapters 6, 7, and 8 are used to calculate the nominal and luminous ranges of existing aid-to-navigation lights or to select optical systems to meet stated operational requirements.

    a. Chapter 5 provides miscellaneous information, including lamp data, flasher characteristics, and luminous intensities required to achieve nominal ranges or 1 to 30 nautical miles.

b. Chapter 6 lists effective luminous intensities of omnidirectional lanterns.

c. Chapter 7 lists effective luminous intensities of rotating beacons.

d. Chapter 8 lists effective luminous intensities of range lanterns.

6. Appendix A lists visibility and transmissivity values for geographic areas along the coast of the United States and the Great Lakes. These values are used to calculate the luminous ranges of Coast Guard aid-to-navigation lights under the conditions specified (i.e., for the 90 or 80 percentile day).

7. Appendix B provides examples of applied procedures for choosing optical systems.

8. Appendix C provides the calculations for performance evaluation of specific optical systems.

9. Appendix D provides a discussion of the method to determine the effective luminous intensity of flashed or rotated lamp systems.

10. A Glossary explains technical terms used in visual signaling engineering.

11. A Bibliography provides a list of the published materials which form the basis for this collation of information.

D. Visual Range Definitions. Visual ranges can be broken into two main categories, **calculated** and **observed** ranges.

1. Calculated Ranges. The category of **calculated ranges** includes the concepts of *luminous*, *nominal*, and *geographic* range.

a. The **luminous range** of a light is the maximum distance at which a light can be seen, as determined by the luminous intensity of the light, the meteorological visibility, and the threshold of illuminance at the eye of an observer.

b. The **nominal range** is the luminous range of a light when the meteorological visibility is 10 nautical miles, and a threshold of illuminance of 0.67 sea-mile candela is used.

c. The **geographic range** of a light is the maximum distance at which the curvature of the earth permits a light to be seen from a particular height of eye, without regard to the luminous intensity of the light.

2. Observed Range. **Observed ranges** reflect the actual circumstances at a specific time and location, including environmental conditions and the psychological state of the observer. Three observed ranges are important in visual signaling: the **detection range**, the **recognition range**, and the **identification range**.

   a. The **detection range** is the distance at which the mariner first sees a light or object. The object may be a ship, land, debris, or an aid to navigation. The detection distance is influenced by the luminance of the object, the background, and the visibility.

   b. The **recognition range** is the distance at which the mariner can state, with a high degree of certainty, the type of object being viewed. For example, a mariner determines that the object is an aid to navigation, but doesn't yet know which specific aid. The recognition range is primarily a function of the shape and color of an object, or the characteristic and color of a light, and the visual acuity of the observer.

   c. The **identification range** is the distance at which the mariner can actually identify the object being viewed. The identification range of a light depends on numerous variables that are probabilistic in nature and will vary with locality and time of year. For lighted aids the recognition and identification ranges will generally be the same.

E. Operational Range. The **operational range** is the distance determined by the waterways manager at which a light should be seen for an established percentage of time. The operational range is based on known hazards, the user groups and their operating area(s), and how the aid is used.

F. Caveats. This Manual provides technical information for Coast Guard standard optical systems only. Other optical systems used as visual signals, such as directional (sector) lights, are not discussed. Directional lights are considered non-standard. If and when they are fully adopted as Coast Guard standard optical systems, this manual will be updated to include the appropriate technical information.

CHAPTER 2. THEORY OF VISUAL SIGNALING

A. Introduction. This chapter discussed the theory of visual signaling. Visual signaling involves three phases: production, transmission, and detection of the signal. Allard's Law establishes how these three phases interact, and allows evaluation of the adequacy of a light signal. Finally, the curvature of the earth places a limit on how far a light may be seen, based on the height of the light and the observer's height of eye.

1. Signal Production. A variety of optics are used to generate aid-to-navigation lights. The signal may use color and/or a flashing characteristic to convey information to the mariner. Section B explains how to determine the luminous intensity produced by a Coast Guard aid-to-navigation light.

2. Signal Transmission. An aid-to-navigation light must be transmitted through the atmosphere. Processes such as absorption, scattering, and the "spreading" of a light signal as it travels from the source, affect the amount of light available as a signal to the mariner. Section C discusses how to evaluate the effects of these processes.

3. Signal Detection. In order to be useful, the signal must be detected and recognized by the mariner. Factors such as background lighting and the psychological and physiological states of the observer determine how bright the signal must be for it to be detected and recognized. Section D provides an explanation of the *threshold of illuminance*, which incorporates these factors.

4. Signal Evaluation. Evaluations of the adequacy of the illuminance provided by a light signal and the physical height of the light, by the use of Allard's Law and by computation of the geographic range, are discussed in Section E.

B. Luminous Intensities of Aids-to-Navigation Lights.

1. General. The Coast Guard uses various combinations of lenses, reflectors, and lamps to produce a light signal. This section describes: (1) light sources used by the Coast Guard; (2) coupling the light source to a lens or reflector; and (3) obtaining luminous intensity measurements for lighted aids to navigation.

2. Light Sources.

a. Incandescent filament lamps are the most commonly used lamps in Coast Guard aids to navigation. Properties of incandescent lamps which are useful in visual signaling include relatively low-power consumption for 12-volt lamps, the ability to be flashed, simple power systems that are easily monitored, low cost, and proven reliability. Incandescent lamps used in Coast Guard aids to navigation have either a vertical coil (C-8) or a vertical, coiled-coil (CC-8) filament. These filaments provide a uniform output in the horizontal plane when used in omnidirectional lanterns.

b. The 12-volt lamps used by the Coast Guard include tungsten filaments in a vacuum or surrounded by an inert gas, and tungsten-halogen lamps. The tungsten filament lamps are rated by amperage, while the tungsten-halogen lamps are rated by wattage. The 120-volt lamps used by the Coast Guard are tungsten-halogen lamps. Lamps differ by voltage, power consumption, light output (luminous flux), size and configuration of the filament, and rated life. Table 5-1 lists data for standard lamps used by the Coast Guard.

c. Flashing a lamp will increase the time over which the lamp life is expended, and may assist mariners in identifying an aid to navigation. Flashing a lamp, however, also decreases the perceived intensity of a lamp from its steady burning value. This apparent reduction in intensity is a physiological effect that occurs for flash lengths less than about 4 seconds. Calculation of the effective luminous intensity for a flashed (or rotated) light is explained later in this section. Standard flash characteristics are presented in Table 5-2.

3. Optical Systems.

a. Light produced by bare lamps must be focused in a direction or directions that maximize their usefulness. Two light beams that are useful for aids to navigation are *fan beams* and *pencil beams*. A fan beam is generated when the light from a lamp is concentrated in the horizontal plane. These beams are generated by optics commonly referred to as omnidirectional lanterns, such as the 155mm lantern. A pencil beam results when the light is concentrated into one or more specific directions. An RL14 range lantern produces a single pencil beam, while the VRB-25 rotating beacon has up to six individual pencil beams. Coast Guard optical systems use various combinations of lenses and reflectors with light sources to produce fan and pencil beams.

b. **Fan beams** are produced by the 155mm, 200mm, 250mm, and 300mm lanterns, and assembled omnidirectional lanterns (classical lenses). These optics use a Fresnel profile to collect light from a source and project it in a horizontal plane. The principle of their design is based on the refractive properties of light; light passing from one medium (air) to another (plastic or glass) will refract or "bend" due to the different indices of refraction of the media. The amount of bending is a function of the angle the ray makes when it contacts the lens and the refractive index of the lens. The lantern designations (e.g., 155mm) are the diameters of the lenses at the focal plane, which are twice the focal length. The focal length is the distance from the focal point to the inside surface of the lens. Light emitted by a lamp at the focal point of the drum lens is refracted by the lens to emerge as horizontal rays.

c. **Pencil beams** are produced by use of a directional lens, or by combining reflectors with light sources. The VRB-25 rotating beacon uses *bull's eye lenses* to produce pencil beams. A bull's eye lens uses a Fresnel profile which is rotated about the optical axis. The VRB-25 has up to six lens panels, each generating a separate pencil beam. The DCB24 and DCB224 rotating beacons, and the RL24 range lantern use a 24-inch parabolic mirror to focus the light from a source into a pencil beam. (The DCB224 rotating beacon uses two optical systems to generate two pencil beams.) The RL14 range lantern uses a 14-inch parabolic mirror to produce a high-intensity pencil beam.

4. Measuring Luminous Intensity.

   a. The International Association of Lighthouse Authorities (IALA) has published recommendations on how to measure the intensity of aid-to-navigation lights. Following these guidelines, the Coast Guard has measured the luminous intensities of standard aid-to-navigation lights in the light tunnel at the Coast Guard Research and Development Center. Data collected for each lens/lamp combination include horizontal and vertical intensity profiles for all optical systems and iso-intensity contours for directional and rotating optics.

   b. The mean horizontal luminous intensity and average vertical beam width are adequate to describe the signal production of an omnidirectional lantern. The mean horizontal luminous intensity is the average peak luminous intensity in the optical plane of a properly focused lantern. The vertical beam width is the angular measurement, in degrees, where the intensity falls to 50 percent of the peak intensity.

   c. For directional lights (rotating beacons and range lanterns), measurements include the peak luminous intensity on axis and the horizontal and vertical beam widths. The horizontal and vertical beam widths listed in the tables are the angular measurements, in degrees, where the intensity falls to 50 percent of the peak intensity. Horizontal intensity profiles are required to evaluate the *effective luminous intensity* of a rotating beacon.

5. Effective Luminous Intensity versus Luminous Intensity.

   a. In general, luminous intensities are measured in the laboratory under "ideal" conditions. Data are obtained for new equipment which are correctly focused and equipped with new lamps operating at design voltage. Furthermore, measurements in the light tunnel provide peak, fixed-on, luminous intensities for optical systems. In actual use, the perceived luminous intensity is affected by battery state of charge, lens and lamp aging, use of color filters, flashing or rotating the light, and placement in a protective housing.

   b. Coast Guard design philosophy does not call for application of correction factors due to lens and lamp aging. Correction factors for losses in luminous intensity due to use of color filters, flashing or rotating the light, and placement in a protective housing (i.e., lantern pane correction), however, are necessary (as appropriate) to calculate the effective luminous intensity of the light signal.

(1) Color factor correction. For incandescent systems, colored lights are produced by shining a white light source through a colored filter. The transmission factor of the filter will vary according to the color desired, the thickness of the filter, and the spectral output of the light source. The luminous intensity of the colored light is calculated by multiplying the intensity of the white light signal by the transmission factor of the colored filter. The filter may be part of the optic (i.e., a colored lens or cover glass) or may be incorporated into the lantern panes. Corrections for colored lenses or cover glasses are incorporated into the tables of luminous intensities provided in this manual. See paragraph (3), below, for colored lantern panes.

(2) Schmidt-Clausen correction. In the case of a fixed light, measuring luminous intensity profiles and vertical and horizontal beam widths provides all the information needed to predict optical performance. No corrections (other than for lantern panes, if applicable) are required. If, however, the light signal is flashed or rotated, then an observer at a given location will see a variation of intensity with time, and an additional correction must be applied. To establish a standard, in December 1980 IALA recommended the *Method of Schmidt-Clausen* to calculate the effective luminous intensity of a flashed or rotated lamp. The Schmidt-Clausen correction factors are incorporated in the data tables in Chapters 6, 7, and 8.

(3) Lantern pane correction. Major lights are usually installed in a lantern; the protective housing on top of a lighthouse. In these cases, it is necessary to correct the measured luminous intensity of the optics to account for losses due to obstruction by the supporting members (astragals), and reflection and transmission losses as light passes through the lantern panes. The Coast Guard uses a correction factor of 0.88 (i.e., 88% transmission) for losses due to clear lantern panes. Red and green acrylic lantern panes have color correction factors of 0.33. Units should request that the supplier provide the transmission factor when lantern pane materials other than acrylic are used.

c. After the applicable correction factors have been applied to the measured luminous intensity of a light, the resulting effective luminous intensity is used to calculate the nominal and luminous ranges of the light. Values of effective luminous intensities listed in the tables in Chapters 5, 6, and 7 already include corrections for colored lenses and the Schmidt-Clausen correction (for flash characteristic or rotation rate). Therefore, the values in these tables are the **effective luminous intensities of the optic**. The only correction factor that may be required when evaluating a light signal, or preparing an aid-to-navigation operation proposal (CG-3213), is for lantern panes (clear or colored), to obtain the **effective luminous intensity of the light signal**.

C. Transmission of Light Through the Atmosphere.

1. General. The second phase of visual signaling involves the transmission of light through the atmosphere. As light travels through the atmosphere it loses energy due to scattering and absorption by particles in the air. The visual signaling terms dealing with these processes are *visibility* or *transmissivity*. In addition to losses incurred in transmission through the atmosphere, the light energy is also spread over an increasingly large area as it travels from the source. This affect is known as the *inverse square law*. Together these factors can be thought of as the transmission losses of a light signal.

2. Meteorological Visibility and Transmissivity. Transmissivity (T) and meteorological visibility (V) are two sides of the same coin; they are measurements of the clarity of the atmosphere. As light travels through air, a portion of the energy is absorbed or scattered by air molecules and particles suspended in the air. Transmissivity may be defined as *the ratio of the amount of light that exits a unit length of atmosphere to the amount of light that entered the atmosphere*. For lighted aids to navigation, transmissivity is normally stated per nautical mile (or sea-mile). Thus, a value of T = 0.90 indicates that 90 percent of the light emitted by a source is transmitted and only 10 percent of the light energy is lost due to atmospheric scattering and absorption after traveling one nautical mile. Meteorological visibility is defined as *the distance required for the atmosphere to reduce the contrast of a black object against its background to 5 percent of the original contrast value at zero distance.* Note that visibility is defined relative to viewing a dark object against its background-it is not the distance at which a light may be seen. Depending on the intensity of a given light, it is possible for the light to be seen well beyond the range of meteorological visibility, or (for low intensity lights) for the light to be undetectable at the limit of visibility. The relationship between transmissivity and meteorological visibility is given as:

$$T^V=0.05, \tag{2-1}$$

solving for visibility yields:

$$V=\frac{\ln(0.05)}{\ln(T)}, \tag{2-2}$$

while solving for transmissivity yields;

$$T=(0.05)^{\frac{1}{V}}. \tag{2-3}$$

In visual signaling, transmissivity is more readily used when accounting for the effects of the atmosphere on the luminous range of a light signal, while visibility is the more readily understood, and measured, value.

3. Visibility and Transmissivity Data. The visibility for a given region depends on the concentration of aerosols, dust, and water vapor in the air. These concentrations vary by location from day to day and even hour to hour. To account for this stochastic nature, visibility measurements made over a long period of time have been plotted, and distribution curves were fitted to the data to correlate visibility with a *percentage of time*.

   a. COMDINST M16500.7 (series) (Aids to Navigation Manual—Administrative) provides guidance on the percentage of time a major or minor aid-to-navigation light should be detectable. Generally, major and minor aids are designed to be detectable at specified distances under visibility conditions corresponding with 90 and 80 percent of the time, respectively.

   b. Appendix A provides the visibility and transmissivity values, in one degree by one degree grids, for 80 and 90 percent of the time for the U.S. coast and the Great Lakes. Given the location of an aid to navigation, these values may be used to calculate the ability of a selected lens/lamp combination to meet the operational range requirements for the desired percentage of time.

4. Inverse Square Law. The inverse square law explains how much light energy is available at the eye of an observer from a light source located at varying distances away, neglecting the affects of the atmosphere. To understand the inverse square law, consider the light output of a lamp as it passes through an invisible sphere centered on the lamp. The surface area of the sphere grows according to the square of its radius, while the light output of the lamp remains fixed. As the sphere grows, the fixed quantity of light is spread over a greater and greater area. The density of the energy at a given distance from the lamp will be inversely proportional to the square of the radius. This may be shown as:

$$E \propto \frac{1}{D^2} \qquad (2\text{-}4)$$

where the illuminance, E, is said to be inversely proportional to the square of the distance, D.

D. Detection of a Light Signal.

1. Threshold of Illuminance. The third phase of visual signaling is detecting the signal. Light from an optical system must have sufficient intensity after traveling through the atmosphere to produce a reaction at the observer's eye. The minimum amount of *illuminance* (perceived brightness) required for an observer to detect a light with a high degree of certainty is called the *threshold of illuminance.* This is a physiological quantity that varies from person to person and, for a given individual, will vary based on the size of the light viewed, color of the light, degree of background lighting, and state of dark adaptation of the observer. An internationally accepted value for mariners is 0.67 *sea-mile candela.* This value assumes a clear, moonlit night, with the observer moderately dark adapted, and with no background lighting.

2. Values of Threshold of Illuminance. The Coast Guard uses values of 0.67 sea-mile candela for the threshold of illuminance when there is no background lighting, 6.7 sea-mile candela for minor background lighting, and 67.0 sea-mile candela for considerable background lighting.

E. Evaluation of a Light Signal.

1. Allard's Law. Allard's Law is the basic equation that relates the illuminance at a given point to the luminous intensity of an optical system and the distance over which the light signal was transmitted. Allard's Law is derived by combining the losses due to absorption and scattering with the reduction in intensity due to the inverse square law. Since the attenuation due to the atmosphere may be defined as the ratio of the light energy leaving a unit length of atmosphere to the amount of light first entering that unit length, for each unit length the illuminance, E, will be reduced by a factor of the transmissivity, T. Thus, for a distance of D nautical miles, the total percentage of light remaining available as a signal, after transmission losses due to the atmosphere, is T times itself D times, or T raised to the power of D (T^D), while the reduction in light energy density, for a sphere of radius D, is accounted for by dividing by D^2. Allard's Law is written:

$$E = \frac{\left(I_e * T^D\right)}{D^2}, \qquad (2\text{-}5)$$

where:

- E = Illuminance (sea-mile candela);
- I_e = Effective luminous intensity of the light signal (candela);
- T = Transmissivity for a given percentage of nights (per nautical mile); and
- D = Distance from the observer to the light (nautical mile).

Allard's Law may be rewritten, using equation 2-3, to substitute the visibility, V, in place of the transmissivity, T:

$$E = \frac{\left(I_e * (0.05)^{\frac{D}{V}}\right)}{D^2}, \tag{2-6}$$

where V is the meteorological visibility (nautical miles).

The equation may also be rewritten to solve for the required effective luminous intensity for a light signal to be detectable at a given distance, D, and for specified values of visibility, V, and threshold of illuminance, E:

$$I_e = \frac{E * D^2}{(0.05)^{\frac{D}{V}}}. \tag{2-7}$$

When Allard's Law (equation 2-7) is solved for a visibility, V, of 10 nautical miles and a threshold of illuminance, E, of 0.67 sea-mile candela, the resulting luminous range is called the **nominal range**. Nominal range is used on nautical charts and in Light Lists to advertise the range at which mariners would expect to see a light, assuming clear conditions and no background lighting. The Coast Guard also uses the concept of nominal range to compare the relative optical performance of lighted aids to navigation.

Allard's Law is also used to determine if the **luminous range** of a light, calculated by substituting in the appropriate value for the visibility for the specified percentage of time at the aid location, and the appropriate threshold of illuminance, meets the requirement for the **operational range**.

2. Geographic Range. An additional factor which must be considered regarding the detection of a light signal is the *geographic range* of the aid-to-navigation light. The geographic range of a light is the distance it can be seen over the horizon (without regarding limitations due to the luminous intensity of the light signal). It is the sum of the *horizon distances* of the light and the observer. The horizon distance is the tangent from the light or observer to the surface of the earth. The Coast Guard uses a corrected horizon distance to account for the refraction, or bending, of light towards the earth. This is discussed more fully in the *American Practical Navigator*, which provides a value for the corrected horizon distance of $D = 1.17 * \sqrt{h}$, where h is the height of the light (in feet), and D is the distance in nautical miles from the light to the horizon. The same relation gives the distance an observer, at a given height-of-eye, can detect a light on the horizon.

Therefore, the geographic range (in nautical miles) is the sum of the horizon distance of the light and the horizon distance of the observer's height-of-eye, or:

$$\text{Geographic Range} = 1.17 * \left(\sqrt{h_1} + \sqrt{h_2}\right), \qquad (2\text{-}8)$$

where h_1 is the height of the light in feet above sea level, and h_2 is the observer's height-of-eye above sea level. Past practice has involved using a value of 15 feet for the observers' heights-of-eye when determining the general geographic range of an aid-to-navigation light. When conducting a WAMS analysis of a waterway, waterways managers should consider using the height-of-eye of the critical user groups for that waterway to determine the appropriate focal height for the lights.

As an additional point of reference, the U.S. Light List publishes a table under the *General Information* section to assist in determining the geographic range of a lighted aid to navigation from its published focal height above sea level.

CHAPTER 3. SELECTING AN OPTICAL SYSTEM

A. Introduction. This chapter describes standard procedures to follow when selecting an optical system for a lighted aid to navigation. Section B includes a general discussion of the lanterns and beacons used on the various types of aids, including lighted buoys, fixed minor lights, major lights, and range lights. Section C outlines the criteria for selection of a specific lens/lamp combination for buoys and minor and major lights, while Section D discusses the selection process for range lights.

The process of determining the required luminous intensity of a light signal has been simplified by development of the Allard's Law Computer Program and the Range Design Computer Program. Chapter 4 of this manual provides instructions on how to use the Allard's Law Computer Program to aid in the selection of the appropriate lens/lamp combination for lighted buoys, fixed minor lights, and major lights. The Range Design Computer Program, and range light selection, are covered in detail in COMDTINST M16500.4 (series); "Range Design Manual."

Users of this manual are cautioned that the nominal range and luminous range of a lighted aid to navigation are not necessarily the distances at which the aid will actually be detected. Rather, these ranges are the distances at which the illuminance provided by the aid should be sufficient for the aid to be detected for very specific atmospheric conditions. Successful detection, however, will also depend upon the sea state, background lighting, and psychological and physiological condition of the observer.

Examples providing further insight into the selection process for optical systems may be found in Appendix B. Examples using the calculations required to evaluate the optical performance of existing optical systems are provided in Appendix C.

B. Aid Type and Optic Selection.

1. Lighted Buoys. Buoys are floating marine markers typically used to mark channels, traffic separation schemes, or hazards. The 155mm lantern is the standard lantern approved for use on buoys. The 200mm lantern may be used on buoys where icing is expected, or where it is anticipated that the lantern may be submerged from time to time. These lanterns can provide a maximum nominal range of 8 nautical miles.

2. Fixed Minor Lights. Fixed minor lights are placed on structures to provide a visual signal to mariners navigating in Inland Waters or along the coast within sight of land. These aids are found on a variety of structures, including single pile and multiple pile structures of wood or steel, concrete posts, spindles, and skeleton towers. Optics used for fixed minor lights include the 155mm, 200mm, 250mm, and 300mm omnidirectional lanterns.

a. The 250mm and 300mm lanterns are only for use on stable platforms and shall not be used on wooden, single pile beacons located in the water. These lanterns require accurate leveling and precision focusing to meet advertised performance levels. They can be installed on steel or concrete beacon structures (in a hard bottom) that are not subject to collisions. All of the 12-volt marine signal lamps, the 12-volt 100W and 110W tungsten-halogen lamps, and the 120-volt 250W lamp may be used in these lanterns. Nominal ranges of up to 12 nautical miles are obtainable.

b. The 200mm lantern is used on beacons where light to moderate icing is anticipated. This lantern may be placed on all types of structures, including wooden, single-pile structures. The 12-volt marine signal lamps, up to and including the 2.03A lamp, may be used in this lantern.

c. The 155mm lantern is, by far, the most predominant optic used on fixed minor aids. It may be placed on all types of structures, but should not be used where icing or breaking water is anticipated. The 155mm lantern may be outfitted with 12-volt marine signal lamps, up to and including the 2.03A lamp.

3. Major Lights. Major lights include both landfall lights and important aids in bays, sounds and along coastal approaches. Major lights are typically associated with lighthouse structures, therefore, usually the optic will be within the lantern (the protective enclosure on top of a lighthouse). A significant feature of a major light is that the height of the optic above sea level is sufficiently high so that the light can be detected at a specified geographic range. The standard optics used as major lights are the DCB24 or DCB224 rotating beacon, and the VRB-25 rotating beacon. In addition, a significant number of assembled lenses (commonly referred to as *classical lenses* or *classical Fresnel lenses*) remain in service.

a. While assembled lenses are no longer considered "standard", and are not used in new installations, they may remain in service almost indefinitely. Therefore, the effective luminous intensities of assembled lenses, from first to sixth-order, are provided with standard Coast Guard omnidirectional lanterns. Assembled lenses may include flash panels, to increase the intensity of the signal in a particular sector, or to provide pencil beams for a rotating optic. The effective luminous intensities of classical flash panels are included with the tables for standard Coast Guard rotating beacons.

b. The DCB24 and DCB224 are the Coast Guard's standard 120-volt rotating beacons. These optics are used for lights that have nominal ranges in excess of 21 nautical miles, and when reliable commercial power is readily available. The DCB24 and DCB224 emit one and two-pencil beams, respectively, that sweep the horizon. The rotation rate of the optic is determined by the specific speed reducer installed.

c. The VRB-25 is the Coast Guard's standard 12-volt rotating beacon. This optic uses an hexagonal array of 180 mm focal length bull's eye lenses, which rotate about a common axis, to produce six pencil beams of light that sweep the horizon. The rotation rate is field selectable.

d. Any of the standard omnidirectional lanterns may be used as a major light if it meets the requirements for the aid.

4. <u>Range Lights</u>. Range lights are used to mark a line of definite bearing, usually the centerline of a channel. A range is a pair of lights that are separated by some distance, and are designed to appear in line with each other when a vessel is traveling in the center of the marked waterway. Range lights are called "leading lights" by IALA because they "lead" a vessel down a channel.

   a. The threshold of illuminance required for range lights is increased by a factor of five over the value used for other aid-to-navigation lights under similar background lighting. A higher illuminance is required for range lights to insure that the lights can be reliably aligned at the far end of the channel.

   b. A range has three unique properties: the minimum acceptable vertical angle between the two lights, the lateral sensitivity of the range, measured by the *cross-track factor*, and the ratio of the illuminances of the two lights, which is called *brightness balance*. These properties are affected by the positions and heights of the range towers, and the range lantern intensities. Designing a range involves a trial and error procedure where tower positions and heights, and lantern intensities are changed in a systematic way to optimize the lateral sensitivity of the range. This is most readily achieved by use of the Range Design Program. COMDTINST M16500.4 (series); "Range Design Manual," describes all aspects of the theory and practice of designing range light systems, and provides specific guidelines for operating the Range Design Program.

   c. Selecting optics for range lights differs from selecting optics for buoys and lights because assembling the necessary range design information requires a significant amount of detailed preparatory work; however, once the data is entered, the Range Design Program recommends intensities which represent the best compromise between conflicting operating conditions. Selecting optics which most closely match the program intensity recommendations will produce a "best-you-can-do" range, using standard signals for the conditions entered.

5. Tables of effective luminous intensities for standard Coast Guard aid-to-navigation lights are found in Chapters 6 (omnidirectional lanterns), 7 (rotating beacons), and 8 (range lanterns) of this manual.

C. Selection Procedures. The procedures for selection of an optic for an aid to navigation (buoys, fixed minor lights, and major lights) are as follows:

STEP 1 State the operational requirement.

The operational requirement should be stated as the desired luminous range of the light for a specified percentage of time. This is known as the *operational range.* Chapter 4 of COMDTINST M16500.7 (series); "AtoN Manual—Administration" specifies that minor lights should meet that requirement 80% of the nights, while major lights should be visible at the operational range 90% of the nights.

EXAMPLE: A lighted major aid is required to provide a signal to mariners navigating along the coast. The light should be detectable at a distance of 14 nautical miles or greater for 90 percent of the time. (NOTE: Do not confuse this requirement with the *nominal range* of the light signal, which is significantly greater for many sections of the U.S. coast.)

STEP 2 Specify additional information about the aid.

Information will typically include the color of the light signal, flash characteristic, location, background lighting, and focal height of the light (if a major aid).

(a) Specify the color of the light signal. In IALA Region B, approaching from seaward, starboard marks are red and port marks are green. Special purpose marks are marked with a yellow light, while aids with no lateral significance may be marked with a white light. Major lights are not held to this convention, but will normally emit white light to achieve the highest possible luminous intensities. Certain sectors of a major light may be colored to indicate caution areas or other specific information (e.g., shoal water). Refer to COMDTINST M16500.7 for guidance on the appropriate colors for intended usage.

(b) Specify the light characteristic. Minor lights (fixed and buoys) will normally display one of the standard flash characteristics listed in Table 5.1. The table lists the characteristics in order of increasing *contact closure time.* Contact closure time is one of the arguments used to enter the tables of effective luminous intensities for omnidirectional lanterns. Major lights may display a nonstandard flash characteristic, however, the contact closure time is still the item of interest. When rotating beacons are used, the characteristic is a direct function of the rotation speed of the optic and the number of pencil beams the optic produces.

STEP 2 (cont'd)

To determine the rotation rate needed for a given characteristic, multiply the number of revolutions per complete characteristic by the time period of the characteristic.

Example #1: What is the rotation rate for a VRB-25 to display Fl W 2.5 sec characteristic? The VRB-25 can provide up to six flashes per revolution:

$$\text{Rotation Rate} = \frac{1\text{ Rev}}{6\text{ Flashes}} * \frac{1\text{ Flash}}{2.5\text{ Sec}} * \frac{60\text{ Sec}}{1\text{ Min}} = 4\text{ rpm.}$$

Example #2: What is the rotation rate for a DCB24 to display Fl W 10 sec characteristic? The DCB24 is limited to one flash per revolution (and, consequently, can not be used for group flash or alternating characteristics):

$$\text{Rotation Rate} = \frac{1\text{ Rev}}{1\text{ Flash}} * \frac{1\text{ Flash}}{10\text{ Sec}} * \frac{60\text{ Sec}}{1\text{ Min}} = 6\text{ rpm.}$$

Example #3: What is the rotation rate for a VRB-25 to provide Fl (2) W 10 sec characteristic? Using four clear (white) lenses and two blanking panels, the VRB-25 provides two sets of the group characteristic (flash-flash-blank) per revolution, while the characteristic requires one complete group every 10 seconds:

$$\text{Rotation Rate} = \frac{1\text{ Rev}}{2\text{ Groups}} * \frac{1\text{ Group}}{10\text{ Sec}} * \frac{60\text{ Sec}}{1\text{ Min}} = 3\text{ rpm.}$$

Example #4: What is the rotation rate for a DCB224 to display Al W R 15 sec characteristic? The DCB224 requires one complete revolution for each display of an alternating characteristic:

$$\text{Rotation Rate} = \frac{1\text{ Rev}}{1\text{ Group}} * \frac{1\text{ Group}}{15\text{ Sec}} * \frac{60\text{ Sec}}{1\text{ Min}} = 4\text{ rpm.}$$

(c) Specify the location of the aid. Truncate the location of the aid to whole degrees of latitude and longitude. The location of the aid will be used to determine the appropriate visibility value used in step 4.

(d) Specify the degree of background lighting. This is necessary to determine a value for the threshold of illuminance.

- No background lighting: E = 0.67 sea-mile candela.
- Minor background lighting: E = 6.7 sea-mile candela.
- Considerable background lighting: E = 67 sea-mile candela.

NOTE	Step 3 is used to calculate the geographic range of major lights only. Proceed to Step 4 for buoys or fixed minor lights.

STEP 3 Determine the geographic range of the light.

Using equation (2-8), the geographic range (in nautical miles) of the light signal is

$$\text{Geographic Range} = 1.17 * \left(\sqrt{h_1} + \sqrt{h_2}\right),$$

where h_1 is the focal height of the light in feet above sea level, and h_2 is the observer's height-of-eye above sea level. Compare the geographic range with the operational range specified in step 1. If the geographic range is less, no optic will be capable of achieving the operational range. The operational requirement should be reconsidered, or the focal height of the light should be increased.

For example, consider a light that is designed to provide a visual signal at a range of 18 nautical miles, to vessels with an average height-of-eye of 36 feet. The optic is mounted at a height of 49 feet above sea level. The geographic range of the light is: $1.17 * \left(\sqrt{49} + \sqrt{36}\right) = 15$ nautical miles. Thus, no optic can meet the stated operational range requirement of 18 nautical miles. The only choices here are to reevaluate the stated operational range, or to raise the focal height of the light. Substituting in the known values, we have:

$$18 \text{ nm} = \left[1.17 * \left(\sqrt{h_1} + \sqrt{36}\right)\right] \text{nm}.$$

Solving for h_1, we find that the required focal height of the light is approximately 88 feet. Note—when a specific user group is not identified, a typical height-of-eye of 15 feet is used to calculate the geographic range of an aid to navigation.

STEP 4 Determine the meteorological visibility, V.

Appendix A lists values for visibility and transmissivity for 80 and 90 percent of the time for the coastal U.S. and the Great Lakes, in one degree by one degree grids. As explained in step 1, the operational range of a major light is based on a requirement to be visible 90 percent of the nights, while a minor light is designed to be visible 80 percent of the nights. Select the appropriate value for visibility.

STEP 5 Calculate luminous intensity (I_e) required to meet the stated operational range.

Using Allard's Law, equation (2-7), calculate the required luminous intensity of the light signal:

$$I_e = \frac{E * D^2}{(0.05)^{\frac{D}{V}}},$$

where:

- D is the stated operational range (nautical miles);
- E is the threshold of illuminance (sea-mile candela); and
- V is the visibility (in nautical miles).

Solve for I_e, the required *effective luminous intensity*. In order to meet the stated operational range requirement, the effective luminous intensity of the selected lens/lamp combination must equal or exceed the value calculated above.

STEP 6 Apply correction factor for lantern panes.

If the optic is enclosed in a *lighthouse lantern*, or other structure with lantern panes, the intensity of the light signal is reduced as it passes through the lantern panes. The light signal is reduced to 88 percent of the effective luminous intensity of the optic when clear lantern panes are used, and to 33 percent of the value for red or green acrylic lantern panes . The required effective intensity of the optic must be corrected to insure that the effective intensity provided by the light signal (outside the lantern panes) meets or exceeds the value obtained in step 5, above. This step is not required for lighted buoys or most fixed minor lights. To determine the required effective luminous intensity of an optic enclosed within clear lantern panes, **divide** the required effective luminous intensity of the light signal (from step 5) by 0.88. For red or green colored lantern panes, divide the effective luminous intensity of the optic by 0.33.

STEP 7 Select optics that meet the operational requirement.

Chapters 6 and 7 present the effective luminous intensities of Coast Guard standard omnidirectional lanterns and rotating beacons. Optics with effective luminous intensities equal to or exceeding the intensity calculated in step 6 will provide a signal that meets the operational range requirement.

Enter Tables 6-1 through 6-5 with the color and flash duration of the light signal to determine if an omnidirectional lantern can meet the operational requirement. If omnidirectional lanterns can not provide sufficient intensity, enter Tables 7-1 through 7-4 with the color of the signal and the appropriate rotation rate of the optic from step 2(b). Optics with effective luminous intensities equal to or greater than

STEP 7 (cont'd) — the corrected effective luminous intensity calculated in step 6 will meet the operational range requirement. If more than one optic meets the requirement for luminous range, a decision needs to be made between competing engineering options as to which optic provides the most cost effective signal for the mariner

D. Selection Procedures for Range Lights. Use the following procedures to select optics for range lights.

STEP 1 — List intensity data from the range design program.

Use the Range Design Program (see COMDTINST M16500.4(series)) to determine the *recommended intensities* for the rear and front range optics. Note—when designing a daytime range, the program only provides values for the *minimum required intensities*.

STEP 2 — Identify optics with acceptable effective intensities.

The tables in Chapter 8 list the effective luminous intensities for standard Coast Guard range lights for standard range characteristics.

STEP 3 — Select a pair of optics to use as range lights.

Select the appropriate lens/lamp combinations which provide the desired intensities (from the Range Design Program), when displaying the selected characteristics, and which have adequate beamwidths to cover the required region, for the front range and rear range lights. Note—the use of omnidirectional lanterns is highly desirable, as the signal can be acquired even when vessels are well off the channel centerline. Use of omnidirectional lanterns also precludes the requirement for additional lights on range towers sited in navigable waters.

CHAPTER 4. ALLARD'S LAW COMPUTER PROGRAM.

A. Introduction. This chapter describes the Allard's Law Computer Program, and provides instructions on its use.

1. Program Description. The Allard's Law Computer Program is an Excel spreadsheet program designed to simplify the process of determining the required luminous intensity to achieve the operational range requirement for a given aid-to-navigation light. The program may also be used to evaluate the effectiveness of a selected optic to meet operational requirements. Inputs to the program are the same as those required for Section 3.C of this manual.

2. Program Calculations. The program determines the effective luminous intensity required to achieve a selected operational range. Also calculated are the actual luminous range provided by a selected optic for a given condition of visibility, the nominal range of the selected optic, and the percentage of time the selected optic will be detectable at the specified operational range.

3. Program Limitations. The program does not select optics which provide effective luminous intensities adequate to meet operational requirements. Selection of optics must be made by reviewing the tables of effective luminous intensities in Chapters 6 and 7 and determining which optics meet the requirements.

B. Program Operation. Load Microsoft Excel and open the file **ALLARDS LAW**. Input cells are highlighted in yellow, while output cells are highlighted in blue. Error messages are generated for improper entries to input cells. Special notes are generated if the visibility at the selected aid location is below a recommended minimum value of 2.0 nm, or if there is no standard optic which can provide the required effective luminous intensity for the stated operational range. Program inputs and outputs are described in the paragraphs below, in the order in which they occur. The program spreadsheet is illustrated in Figure 4-1.

C. Part 1: Find Effective Intensity Required to Meet Operational Need. This section describes the inputs, outputs, and messages which are encountered in Part 1 of the Allard's Law Computer Program.

1. Program Inputs. Only input data in the yellow-highlighted cells. While data may be entered in any order, it is recommended that when a site is first evaluated that data be entered in order.

a. Aid Name—Enter the name of the aid.

b. Latitude—Round DOWN to whole degrees (i.e., 43° 03.5' is entered as 43).

c. Longitude—Round DOWN to whole degrees (i.e., 70° 41.8' is entered as 70).

d. Operational Range—The desired luminous range (in nm) of the light for a specified percentage of time (see Chapter 4 of COMDTINST M16500.7 for guidance). This will normally be a whole number (e.g., 9).

e. Aid Type—Enter the aid type ("minor" or "major"):

- Minor—for lighted buoys and fixed minor lights.
- Major—for major lights.

f. Lantern Pane—Enter the appropriate description for lantern panes (i.e., "none," "clear," "red," or "green.")

g. Background Lighting—Enter the appropriate description of background lighting (i.e., "none," "minor," or "considerable").

2. Visibility/Transmissivity Data. The program uses the aid position information (latitude and longitude) and the aid type to determine the meteorological visibility for the location on the appropriate percentile day. COMDTINST M16500.7 specifies that for minor aids the appropriate percentile day (percentage of time an aid should be detectable at a specified distance) is 80%, while for a major aid it is 90%.

a. Visibility(xx%)—The meteorological visibility (in nm) for the aid position. The program returns a value of 80% or 90% in the parentheses.

b. Transmissivity(xx%)—The transmissivity which correlates to the meteorological visibility, above.

Note 1: If the meteorological visibility for the aid location and percentile day is less than 2 nm, the program returns a value of 2 nm for visibility and the percentage of time that the visibility is equal to or greater than 2 nm at that position. This is a default value for determining required effective luminous intensity for an aid. Visibility values less than 2 nm should not be used. The correlating value of transmissivity is also provided.

Note 2: If there is no data for the selected aid position, the program will return a statement "UNKNOWN," for visibility and transmissivity. A value for the meteorological visibility will have to be entered manually in the next section of the program, entitled "Modifications."

3. Modifications. This portion of the program allows the user to override the value returned for the meteorological visibility, or to enter a value for visibility when no data exists for the selected aid position. Enter an integer value (e.g., 3). The minimum value recommended for use is 2.

4. Program Outputs. The Allard's Law Computer Program will return a value for the required effective luminous intensity of the optic to meet the stated operational range at the selected aid position. This value includes corrections for lantern panes and

background lighting conditions. Enter the tables in Chapters 6 and 7 of this manual to select optics which can provide the required intensity.

Note 1: The program will provide a statement when the required luminous intensity is beyond the capability of existing standard Coast Guard aids-to-navigation lighting hardware. You may proceed to Part 2 of the program nonetheless, to determine the performance of a selected optic against the stated operational requirement.

D. Part 2: Find Performance of Selected Optic. In this part of the Allard's Law Computer Program, the performance of the selected visual signal (lens/lamp combination and characteristic) will be evaluated.

1. Lens/Lamp Combination. Enter the information required to describe the signal.

   a. Selected Optic—Enter the appropriate nomenclature of the lantern/beacon (155mm, 250mm, 300mm, VRB-25, DCB24, DCB224).

   b. Lamp—Enter the selected lamp (e.g., "12V, 0.77A" or "120V, 250W")

   c. Signal Color—Enter the color of the light signal. For sectored lights or an alternating characteristic, the program must be run separately for each color.

   d. Characteristic—For an omnidirectional lantern, enter the characteristic (less the color designator) generated by the flasher (e.g., "Fl 6(0.6)" or "Occ 4"). For a rotating beacon, enter the rotation rate (e.g., "2 rpm").

   e. Effective Intensity—Enter the luminous intensity provided by the selected lens/lamp combination for the given color and characteristic (from the tables in Chapters 6 and 7). The program will return a value for the effective intensity of the light signal, after accounting for lantern pane losses.

2. Aid Performance. Using information from Part 1, and the effective intensity entered above, the program evaluates the performance of the selected lens/lamp combination.

   a. Luminous Range of Light When Visibility = x.x nm—The program returns the distance at which the light should be detectable for a given condition of visibility and background lighting. The visibility condition is also returned.

   b. Nominal Range of Light—The program returns the nominal range of the light.

   c. % Time Light is Detectable at Operational Range of x.x nm—Based on the visibility data for the selected aid position, the program returns the actual percentage of time that the luminous range of the light meets or exceeds the operational range. If no meteorological data exists for the selected aid position, the program will return the statement "UNKNOWN," and advise that data is not available for the site.

3. Figure 4-1 is a snapshot of the Allard's Law Computer Program Spreadsheet, completed for a fictitious light located in the 35N 077W grid. The lighter shaded boxes are those which are to be filled in by the aid designer/reviewer, while the darker shaded boxes contain values returned by the program.

PART 1: FIND EFFECTIVE INTENSITY REQUIRED TO MEET OPERATIONAL NEED

Program Inputs:

Aid Name:	Whozit Light	
Latitude of Aid:	35	degrees (round DOWN to whole degree)
Longitude of Aid:	77	degrees (round DOWN to whole degree)
Operational Range:	12	nm
Aid Type:	major	(enter minor or major)
Lantern Pane:	clear	(enter none, clear, red, or green)
Background Lighting:	none	(enter none, minor, or considerable)

Visibility/transmissivity data:

Visibility(90%):	[redacted]	(90% of the time visibility is at least 5.8 nm)
Transmissivity(90%):	[redacted]	(90% of the time transmissivity is at least 0.60)

Modifications:

Visibilty (nm):		(enter a visibility value ONLY IF you want to override the 5.8 nm visibility provided above.)

Program Output:

Required intensity:	[redacted]	**of OPTIC, in candela**

PART 2: FIND PERFORMANCE OF SELECTED OPTIC

Lens/Lamp Combination:

Selected Optic:	DCB-24	
Lamp:	120V, 1000W	
Signal Color:	red	(signal color of optic)
Characteristic:	Fl 10	
Effective Intensity:	99,000	of OPTIC, in candela
Effective Intensity:	[redacted]	of the LIGHT, in candela

Aid Performance:

Luminous Range of Light When Visibility = 5.8 nm: [redacted]
Nominal Range of Light:
% Time Light is Detectable at Operational Range of 12.0 nm:

Figure 4-1. Allard's Law Computer Program Worksheet.

CHAPTER 5. TABLES OF STANDARD DATA.

A. Introduction. This chapter provides tables on standard flash characteristics (Table 5-1), lamp data (Table 5-2), the Blondel-Rey Correction Factors for Rotating Flash Panels (Table 5-3), and Nominal Range versus Luminous Intensity (Table 5-4).

1. Table 5-1 lists the standard flash characteristics for use with aid-to-navigation lights, by increasing contact closure time and duty cycle. Standard characteristics are stocked in the supply fund. Characteristics other than those listed in Table 5-1 may by purchased from vendors whose products have been accepted as meeting the requirements of U.S. Coast Guard Specification G-SEC-181. Information on approved vendors may be obtained from Commandant (G-SEC-2).

TABLE 5-1.

STANDARD COAST GUARD FLASH CHARACTERISTICS

Contact Closure Time (seconds)	Flash Characteristic	Timing ON/OFF (seconds)	Duty Cycle
0.3	Fl 2.5 (0.3)	0.3/2.2	0.12
0.3	Fl (2+1) 6	0.3/0.4/0.3/1.2/0.3/3.5	0.15
0.3	Q	0.3/0.7	0.30
0.4	Fl 4 (0.4)	0.4/3.6	0.10
0.4	Fl (2) 5	0.4/0.6/0.4/3.6	0.16
0.4	Mo (A) (0.4, 2.0)	0.4/0.6/2.0/5.0	0.30
0.6	Fl 6 (0.6)	0.6/5.4	0.10
1.0	Fl (2) 6	1.0/1.0/1.0/3.0	0.33
1.0	Fl 2.5 (1)	1.0/1.5	0.40
1.0	Iso 2	1.0/1.0	0.50
3.0	Iso 6	3.0/3.0	0.50
3.0	Occ 4	3.0/1.0	0.75
—	Fix	—	1.00

Note: The standard characteristics for use on ranges are:

Front: Q, Fl 2.5 (1), and Iso 2.
Rear: Iso 6, Occ 4, and Fix.

2. Table 5-2 provides miscellaneous information on 12-volt and 120-volt lamps used by the U.S. Coast Guard for lighted aids to navigation. All of the 12-volt lamps; including the standard marine signal lamps (0.25A, 0.55A, etc.), the CC-8 lamps, and the tungsten-halogen lamps, are stocked in the supply fund. The 120-volt, 150W and 250W lamps should be purchased commercially from lamp distributors. The 1000W lamps are stocked in the supply fund.

TABLE 5-2.

LAMP DATA FOR COAST GUARD 12V AND 120V LAMPS

Rated Input	Luminous Flux (lumens)	Filament Type	Filament Width (mm)	Height (mm)	Lamp Life (hours)
12V 0.25A	30	C-8	0.15	6.0	500
0.55A	70	C-8	0.20	5.5	500
0.77A	120	C-8	0.30	7.0	500
1.15A	180	C-8	0.40	7.0	500
2.03A	380	C-8	0.60	8.0	500
3.05A	600	C-8	0.80	9.3	500
12V 1.0A	145	CC-8	1.15	2.0	1000
1.9A	390	CC-8	1.50	4.0	1000
3.0A	600	CC-8	1.90	5.5	1000
12V 35W	630	C-8	1.15	2.0	2000
50W	975	C-8	1.50	4.0	2000
75W	1,575	C-8	1.50	4.0	2000
100W	2,400	C-8	1.50	4.0	2000
110W	2,700	C-8	1.62	5.65	600
120V 150W	2,600	CC-8	1.5	16.7	2000
250W	4,850	CC-8	3.0	17.7	2000
1000W	21,700	CC-8	6.3	27.0	3000

3. Table 5-3 lists the Blondel-Rey Correction Factors for Rotating Flash Panels. These correction factors are used to obtain the effective luminous intensity for rotating classical (assembled) lenses. The table is entered by multiplying the rotation rate of the lens assembly (R), times the form factor (F) of the flash panel. The form factors for classical (assembled) flash panels are found in Table 7-3, Uncorrected Intensities, Classical Flash Panels.

TABLE 5-3.

BLONDEL-REY CORRECTION FACTORS FOR ROTATING FLASH PANELS

RxF	B-R	RxF	B-R	RxF	B-R
2	.907	100	.362	900	.078
2.5	.895	120	.330	1000	.071
3	.880	140	.308	1200	.061
4	.860	150	.292	1400	.053
5	.838	160	.282	1500	.050
6	.820	180	.264	1600	.047
7	.800	200	.247	1800	.042
8	.790	225	.228	1900	.040
9	.778	250	.212	2100	.037
10	.760	275	.199	2200	.035
15	.710	300	.187	2500	.031
20	.664	350	.166	2600	.030
25	.627	400	.151	2700	.029
30	.593	450	.138	2800	.028
40	.538	500	.128	2900	.027
50	.490	550	.118	3200	.025
60	.462	600	.111	3300	.024
70	.431	650	.103	3600	.022
80	.407	700	.097	3800	.021
90	.382	800	.087	4000	.020

Example: What is the effective luminous intensity for a fourth order lens, with 90 degree flash panels, rotating at 3 rpm, and outfitted with the 120-volt 1000W lamp?

a. From Table 7-3, the uncorrected intensity for the given lens/lamp combination is 1,100,000 candela, and the form factor (F) is 75.

b. The B-R factor, from Table 5-3, is equal to: RxF = 225, B-R = 0.228.

c. A fourth order lens would normally be enclosed in a lighthouse lantern. A correction factor of 0.88 must be applied to account for lantern pane losses. Therefore, the effective luminous intensity of the signal is:

$$I_e = 0.88 \times 0.228 \times 1{,}100{,}000 \text{ candela} \cong 220{,}000 \text{ candela.}$$

4. Table 5-4 lists nominal range (in nautical miles) versus the effective luminous intensities required to achieve the stated range. Note that nominal range is provided as an integer value.

TABLE 5-4

NOMINAL RANGE VS EFFECTIVE LUMINOUS INTENSITY

Effective Luminous Intensity (candela)			Nominal Range (nautical miles)
1	to	2	1
2	to	10	2
10	to	25	3
25	to	55	4
55	to	110	5
110	to	200	6
200	to	360	7
360	to	630	8
630	to	1,100	9
1,100	to	1,800	10
1,800	to	2,800	11
2,800	to	4,500	12
4,500	to	7,000	13
7,000	to	11,000	14
11,000	to	17,000	15
17,000	to	26,000	16
26,000	to	40,000	17
40,000	to	60,000	18
60,000	to	90,000	19
90,000	to	135,000	20
135,000	to	200,000	21
200,000	to	295,000	22
295,000	to	435,000	23
435,000	to	635,000	24
635,000	to	930,000	25
930,000	to	1,350,000	26
1,350,000	to	2,000,000	27
2,000,000	to	2,850,000	28
2,850,000	to	4,200,000	29
4,200,000	to	6,000,000	30

CHAPTER 6. EFFECTIVE LUMINOUS INTENSITIES OF OMNIDIRECTIONAL LANTERNS

A. Introduction. This chapter provides tables on the effective luminous intensities for standard omnidirectional lanterns, including the 155mm lantern (Table 6-1), 200mm lantern (Table 6-2), 250mm lantern (Table 6-3), and 300mm lantern (Table 6-4). The effective luminous intensities for classical (assembled) omnidirectional lenses (Table 6-5) are also provided.

1. Table 6-1 lists the effective luminous intensities for the 155mm lantern outfitted with 12-volt marine signal lamps, up to and including the 2.03A lamp. The table is broken down by lens color, lamp size, and contact closure time. Note that CC-8 filament lamps and tungsten-halogen lamps cannot be used in the 155mm lantern. This lantern may be placed on all types of structures, including wooden, single-pile structures.

TABLE 6-1.

EFFECTIVE LUMINOUS INTENSITIES—155 MM LANTERN (ACRYLIC LENS)

Lens	Lamp	CONTACT CLOSURE TIME (seconds)								
		0.3	0.4	0.5	0.6	0.8	1	2	3	Fixed
		Effective Luminous Intensity (candela)								
Clear	12V 0.25A	25	30	35	35	40	40	45	45	50
	0.55A	60	70	80	85	90	95	110	110	120
	0.77A	90	110	120	130	140	150	160	170	180
	1.15A	120	150	160	180	190	210	230	240	260
	2.03A	190	260	300	330	370	390	440	460	500
Yellow	12V 0.25A	20	25	25	25	30	30	35	35	35
	0.55A	45	55	60	65	70	70	80	85	90
	0.77A	65	80	90	95	100	110	120	120	130
	1.15A	85	110	120	130	140	150	170	180	190
	2.03A	140	190	220	240	270	290	330	340	370
Red	12V 0.25A	8	9	10	10	10	10	15	15	15
	0.55A	20	20	25	25	25	30	30	35	35
	0.77A	25	30	35	35	40	40	45	50	50
	1.15A	35	40	45	50	55	60	65	70	75
	2.03A	55	75	85	95	110	110	130	130	140
Green	12V 0.25A	10	10	10	15	15	15	15	15	20
	0.55A	20	25	30	30	35	35	40	40	45
	0.77A	35	40	45	45	50	55	60	60	65
	1.15A	40	55	60	65	70	75	85	85	95
	2.03A	70	90	110	120	130	140	160	170	180

2. Table 6-2 lists the effective luminous intensities for the 200mm lantern (glass lens) outfitted with 12-volt marine signal lamps, up to and including the 3.05A lamp. The table is broken down by lens color, lamp size, and contact closure time. Note that CC-8 filament lamps and tungsten-halogen lamps cannot be used in the 200mm lantern. The 200mm lantern is used on beacons where light to moderate icing is anticipated. This lantern may be placed on all types of structures, including wooden, single-pile structures.

TABLE 6-2.

EFFECTIVE LUMINOUS INTENSITIES—200MM LANTERN (GLASS LENS)

Lens	Lamp	CONTACT CLOSURE TIME (seconds)								
		0.3	0.4	0.5	0.6	0.8	1	2	3	Fixed
		Effective Luminous Intensity (candela)								
Clear	12V 0.25A	15	20	20	20	25	25	25	30	30
	0.55A	40	45	55	55	60	65	70	75	80
	0.77A	60	70	80	85	90	95	110	110	120
	1.15A	80	100	110	120	130	140	160	170	180
	2.03A	150	190	230	250	280	300	340	350	380
	3.05A	—	230	280	320	370	400	460	480	520
Yellow	12V 0.25A	8	9	10	10	10	10	15	15	15
	0.55A	20	20	25	25	25	30	30	35	35
	0.77A	25	30	35	40	40	45	50	50	55
	1.15A	35	45	50	55	60	65	75	75	80
	2.03A	65	85	100	110	130	130	150	160	170
	3.05A	—	100	130	140	170	180	210	210	230
Red and Green	12V 0.25A	3	4	4	4	5	5	5	6	6
	0.55A	8	9	10	10	10	15	15	15	15
	0.77A	10	15	15	15	20	20	20	20	25
	1.15A	25	20	25	25	35	30	30	35	35
	2.03A	30	40	45	50	55	60	70	70	75
	3.05A	—	45	55	65	75	80	95	95	100

3. Table 6-3 lists the effective luminous intensities for the 250mm lantern outfitted with 12-volt marine signal lamps, up to and including the 3.05A lamp, and the 120-volt 250W lamp. The table is broken down by lens cover color, lamp size, and contact closure time. Note that the 12-volt CC-8 filament lamps and tungsten-halogen lamps cannot be used in the 250mm lantern.

- The standard 250mm lantern can dissipate the equivalent of 75W continuously. This restricts the 120-volt 250W lamps to 30-percent duty cycles.
- A vented 250mm lantern can dissipate up to 200W continuously, allowing an 80-percent duty cycle for 250W lamps.
- When a reflex reflector is used, increase the listed intensities by 30 percent in the 60 degree horizontal arc directly across from each reflector.
- The effective luminous intensities of the 250mm lantern with condensing panels are provided in Chapter 8, Effective Luminous Intensities of Range Lanterns.

TABLE 6-3.

EFFECTIVE LUMINOUS INTENSITIES—250MM LANTERN (ACRYLIC LENS)

Lens	Lamp	CONTACT CLOSURE TIME (seconds)								
		0.3	0.4	0.5	0.6	0.8	1	2	3	Fixed
		Effective Luminous Intensity (candela)								
Clear	12V 0.25A	40	45	45	50	55	55	65	65	70
	0.55A	90	110	120	130	140	150	160	170	180
	0.77A	130	160	180	190	200	220	240	250	270
	1.15A	180	220	250	280	300	320	360	370	400
	2.03A	300	390	460	510	570	600	680	720	770
	3.05A	—	460	570	640	740	810	930	970	1,100
	120V 250W	1,700	2,300	2,700	2,900	3,300	3,500	4,000	4,100	4,400
Yellow	12V 0.25A	25	30	35	35	40	40	45	45	50
	0.55A	65	75	85	90	95	100	110	120	130
	0.77A	95	110	130	130	150	160	170	180	190
	1.15A	130	160	180	200	210	230	260	260	280
	2.03A	210	280	330	360	400	430	490	510	550
	3.05A	—	330	400	450	530	570	660	690	750
	120V 250W	1,200	1,600	1,900	2,100	2,300	2,500	2,800	2,900	3,200
Red and Green	12V 0.25A	10	15	15	15	15	20	20	20	20
	0.55A	30	35	35	40	45	45	50	50	55
	0.77A	40	50	55	60	65	70	75	80	85
	1.15A	55	70	80	85	95	100	110	120	120
	2.03A	95	120	140	160	180	190	210	220	240
	3.05A	—	140	170	200	230	250	290	300	320
	120V 250W	540	700	830	910	1,000	1,100	1,200	1,300	1,400

4. Table 6-4 lists the effective luminous intensities for the 300mm lantern outfitted with 12-volt marine signal lamps up to and including the 3.05A lamp, the 12-volt 110W tungsten-halogen lamp, and the 120-volt 250W lamp. The table is broken down by lens color, lamp size, and contact closure time. Note that the 12-volt CC-8 filament lamps and tungsten-halogen lamps (other than the 12V 110W lamp) cannot be used in the 300mm lantern.

TABLE 6-4.

EFFECTIVE LUMINOUS INTENSITIES—300MM LANTERN (ACRYLIC LENS)

Lens	Lamp	CONTACT CLOSURE TIME (seconds)								
		0.3	0.4	0.5	0.6	0.8	1	2	3	Fixed
		Effective Luminous Intensity (candela)								
Clear	12V 0.25A	55	65	70	75	80	80	95	90	100
	0.55A	130	150	170	180	200	210	230	240	260
	0.77A	200	240	260	280	300	320	360	370	400
	1.15A	250	310	350	380	410	440	500	510	550
	2.03A	410	540	630	690	780	820	930	980	1,100
	3.05A	—	660	810	910	1,100	1,200	1,300	1,400	1,500
	12V 110W	—	—	—	3,000	3,700	4,100	5,200	5,500	6,000
	120V 250W	2,500	3,300	3,900	4,300	4,800	5,100	5,800	6,000	6,500
Yellow	12V 0.25A	35	40	45	45	50	55	60	60	65
	0.55A	85	100	110	120	130	140	150	160	170
	0.77A	130	160	170	180	200	210	230	240	260
	1.15A	160	200	230	250	270	290	320	330	360
	2.03A	270	350	410	450	500	530	610	630	680
	3.05A	—	430	530	590	690	750	870	900	970
	12V 110W	—	—	—	1,900	2,300	2,600	3,300	3,500	3,800
	120V 250W	1,600	2,100	2,500	2,800	3,100	3,300	3,700	3,900	4,200
Red and Green	12V 0.25A	15	20	20	20	20	25	25	25	30
	0.55A	35	45	50	50	55	60	65	70	75
	0.77A	55	65	75	80	85	90	100	100	110
	1.15A	70	85	95	110	120	120	140	140	150
	2.03A	110	150	180	190	220	230	260	270	290
	3.05A	—	180	230	260	300	320	370	390	420
	12V 110W	—	—	—	700	880	990	1,300	1,300	1,400
	120V 250W	710	920	1,100	1,200	1,300	1,400	1,600	1,700	1,800

5. Table 6-5 lists the effective luminous intensities for classical (assembled) omnidirectional lenses. The table is broken down by lens order, lamp size, and contact closure time. Color correction factors must be applied separately. Note that First, Second, and Third Order lenses may only be outfitted with the 120-volt 1000W lamp. Smaller lens may use either the 120-volt 1000W lamp or the 250W lamp. The values provided in Table 6-5 are for assembled lenses in good condition which contain a central dioptric section and upper and lower catadioptic sections. For lanterns which do not meet those criteria, consult with Commandant (G-SEC) for assistance in determining the effective luminous intensity.

TABLE 6-5.

EFFECTIVE LUMINOUS INTENSITIES—CLASSICAL (ASSEMBLED) LENSES

Order	Lamp	Contact Closure Time (seconds)								
		0.3	0.4	0.5	0.6	0.8	1	2	3	Fixed
		Effective Luminous Intensity (candela)								
1	120V 1000W	—	—	—	31,000	40,000	45,000	57,000	60,000	65,000
2	120V 1000W	—	—	—	25,000	32,000	37,000	46,000	49,000	53,000
3	120V 1000W	—	—	—	21,000	27,000	30,000	38,000	40,000	44,000
3.5	120V 250W	4,700	6,100	7,200	7,900	8,900	9,400	11,000	11,000	12,000
	1000W	—	—	—	18,000	23,000	26,000	32,000	34,000	37,000
4	120V 250W	3,500	4,600	5,400	5,900	6,700	7,000	8,000	8,400	9,000
	1000W	—	—	—	13,000	17,000	19,000	24,000	26,000	28,000
5	120V 250W	2,900	3,800	4,500	4,900	5,500	5,800	6,700	7,000	7,500
	1000W	—	—	—	12,000	15,000	17,000	21,000	22,000	24,000
6	120V 250W	2,600	3,400	4,000	4,400	5,000	5,200	6,000	6,200	6,700
	1000W	—	—	—	11,000	13,000	15,000	19,000	20,000	22,000

CHAPTER 7. EFFECTIVE LUMINOUS INTENSITIES OF ROTATING BEACONS

A. Introduction. This chapter provides tables on the effective luminous intensities for standard rotating beacons, including the DCB24 and DCB224 beacons (Table 7-1), and the VRB-25 rotating beacon (Table 7-2). The uncorrected peak beam intensities for classical (assembled) flash panels (Table 7-3) are also provided.

1. Table 7-1 lists the effective luminous intensities for the DCB24 and DCB224 beacons. The table is broken down by lens color and rotation rate. Since both beacons use the same optical drum, the effective intensities for a given rotation rate are the same for both beacons. The difference is that a DCB224 will provide a group flash characteristic, of a given intensity, within the same time period as a DCB24 will provide a single flash. When configured with the optical drums 180 degrees in opposition, the DCB224 will provide a simple flash characterisitic at half the time interval of a DCB24 at the same rotation rate.

   - The only lamp used in the DCB24 and DCB224 beacons is the 120V 1000W tungsten-halogen lamp.
   - The color correction factors for glass cover lenses for the DCB24 and DCB224 beacons are: 0.22 (red), 0.20 (green). These factors were used to calculate the effective luminous intensity of the optic with colored lens installed. When acrylic filters (with standoffs) are used to provide a colored light signal, multiply the effective luminous intensity of the beacon with a clear lens times the transmission factor of the acrylic filter.
   - The number beneath the effective luminous intensity is the apparent flash length, in seconds.

TABLE 7-1.

EFFECTIVE LUMINOUS INTENSITIES—DCB24 AND DCB224 BEACONS

Lens	Rotation Rate (rpm)								
	1	2	3	4	5	6	10	12	Fixed
	Effective Luminous Intensity (candela)								
Clear	1,200,000 0.31	860,000 0.20	690,000 0.15	580,000 0.12	510,000 0.10	450,000 0.09	310,000 0.06	270,000 0.05	2,500,000 —
Red	260,000 0.31	190,00 0.20	150,000 0.15	130,000 0.12	110,000 0.10	99,000 0.09	68,000 0.06	59,000 0.05	550,000 —
Green	240,000 0.31	170,000 0.20	140,000 0.15	120,000 0.12	100,000 0.10	90,000 0.09	62,000 0.06	54,000 0.05	500,000 —

2. Tables 7-2a through 7-2c lists the effective luminous intensities for the VRB-25 rotating beacon. The tables are broken down by lamp size and rotation rate. Table 7-2a is for the VRB-25 with clear lens panels, Table 7-2b is with red lens panels, and Table 7-2c is with green lens panels. The VRB-25 uses six lens panels, in any combination of colors and blanking panels, to provide a wide variety of simple flash, group flash, alternating, or group alternating characteristics. The VRB-25 may be outfitted with any of the 12-volt lamps, from the 0.77A lamp and larger.

TABLE 7-2a.

EFFECTIVE LUMINOUS INTENSITIES—VRB-25 ROTATING BEACON

—**WHITE**—

Lamp	Rotation Rate										Peak
	2/3	1	1-1/3	1-1/2	1-2/3	2	2-1/2	3	4	5	
	Effective Intensity (candela)										
0.77A	13,000	10,000	8,100	7,400	6,700	5,800	4,800	4,100	3,100	2,500	41,000
1.15A	21,000	15,000	12,000	11,000	10,000	8,700	7,100	6,000	4,600	3,800	70,000
2.03A	38,000	29,000	24,000	21,000	20,000	17,000	14,000	12,000	9,300	7,600	100,000
3.05A	51,000	39,000	31,000	29,000	26,000	23,000	19,000	16,000	12,000	10,000	130,000
1.0A(CC-8)	32,000	25,000	20,000	18,000	17,000	14,000	12,000	10,000	7,900	6,400	83,000
1.9A(CC-8)	57,000	44,000	36,000	32,000	30,000	26,000	21,000	18,000	14,000	12,000	150,000
3.0A(CC-8)	78,000	61,000	50,000	46,000	42,000	37,000	31,000	26,000	20,000	17,000	180,000
35W	100,000	77,000	62,000	57,000	52,000	45,000	38,000	32,000	25,000	20,000	250,000
50W	130,000	100,000	83,000	76,000	69,000	60,000	50,000	43,000	33,000	27,000	320,000
75W	170,000	140,000	110,000	100,000	95,000	82,000	69,000	59,000	46,000	38,000	380,000
100W	220,000	170,000	140,000	130,000	120,000	110,000	89,000	77,000	60,000	49,000	470,000
110W	240,000	190,000	150,000	140,000	130,000	110,000	92,000	79,000	61,000	50,000	600,000

TABLE 7-2b.

EFFECTIVE LUMINOUS INTENSITIES—VRB-25 ROTATING BEACON

—RED—

Lamp	Rotation Rate										Peak
	2/3	1	1-1/3	1-1/2	1-2/3	2	2-1/2	3	4	5	
	Effective Intensity (candela)										
0.77A	3,900	3,000	2,400	2,200	2,000	1,700	1,400	1,200	930	750	12,000
1.15A	6,300	4,500	3,600	3,300	3,000	2,600	2,100	1,800	1,400	1,100	21,000
2.03A	11,000	8,700	7,200	6,300	6,000	5,100	4,200	3,600	2,800	2,300	30,000
3.05A	15,000	12,000	9,300	8,700	7,800	6,900	5,700	4,800	3,600	3,000	39,000
1.0A(CC-8)	9,600	7,500	6,000	5,400	5,100	4,200	3,600	3,000	2,400	1,900	25,000
1.9A(CC-8)	17,000	13,000	11,000	9,600	9,000	7,800	6,300	5,400	4,200	3,600	45,000
3.0A(CC-8)	23,000	18,000	15,000	14,000	13,000	11,000	9,300	7,800	6,000	5,100	54,000
35W	34,000	26,000	21,000	19,000	18,000	15,000	13,000	11,000	8,500	6,800	85,000
50W	44,000	34,000	28,000	26,000	23,000	20,000	17,000	15,000	11,000	9,200	110,000
75W	58,000	48,000	37,000	34,000	32,000	28,000	23,000	20,000	16,000	13,000	130,000
100W	75,000	58,000	48,000	44,000	41,000	37,000	30,000	26,000	20,000	17,000	160,000
110W	79,000	62,000	51,000	46,000	43,000	37,000	31,000	27,000	21,000	17,000	200,000

TABLE 7-2c.

EFFECTIVE LUMINOUS INTENSITIES—VRB-25 ROTATING BEACON

—**GREEN**—

Lamp	Rotation Rate										Peak
	2/3	1	1-1/3	1-1/2	1-2/3	2	2-1/2	3	4	5	
	Effective Intensity (candela)										
0.77A	4,900	3,800	3,100	2,800	2,500	2,200	1,800	1,600	1,200	950	16,000
1.15A	8,000	5,700	4,600	4,200	3,800	3,300	2,700	2,300	1,700	1,400	27,000
2.03A	14,000	11,000	9,100	8,000	7,600	6,500	5,300	4,600	3,500	2,900	38,000
3.05A	19,000	15,000	12,000	11,000	9,900	8,700	7,200	6,100	4,600	3,800	49,000
1.0A(CC-8)	12,000	9,500	7,600	6,800	6,500	5,300	4,600	3,800	3,000	2,400	32,000
1.9A(CC-8)	22,000	17,000	14,000	12,000	11,000	9,900	8,000	6,800	5,300	4,600	57,000
3.0A(CC-8)	30,000	23,000	19,000	17,000	16,000	14,000	12,000	9,900	7,600	6,500	68,000
35W	43,000	33,000	27,000	25,000	22,000	19,000	16,000	14,000	11,000	8,600	110,000
50W	56,000	43,000	36,000	33,000	30,000	26,000	22,000	18,000	14,000	12,000	140,000
75W	73,000	60,000	47,000	43,000	41,000	35,000	30,000	25,000	20,000	16,000	160,000
100W	95,000	73,000	60,000	56,000	52,000	47,000	38,000	33,000	26,000	21,000	200,000
110W	100,000	79,000	64,000	59,000	54,000	47,000	39,000	34,000	26,000	21,000	260,000

3. Table 7-3 provides the uncorrected peak intensities, Blondel-Rey Form Factor (F), and apparent flash duration (T) in seconds for classical (assembled) flash panels. The effective luminous intensity for a rotating classical (assembled) lens is obtained by entering Table 5-3, Blondel-Rey Correction Factors for Rotating Flash Panels, with the product of the rotation rate times the Blondel-Rey Form Factor (F), for a selected lens/lamp combination, to obtain the Blondel-Rey Correction Factor.

- Lamps listed are the 120V 1000W and 120V 250W tungsten-halogen lamps.
- I is the fixed peak beam intensity.
- F is the Blondel-Rey Form Factor.
- T is the apparent flash length, in seconds, for a rotation rate of 1 rpm.

TABLE 7-3.

UNCORRECTED PEAK INTENSITIES—CLASSICAL (ASSEMBLED) FLASH PANELS

Lens Order	Size	Lamp	I (candelas)	F	T @ 1 RPM
4	90°	1000 W	1,100,000	75	.24
4	90°	250 W	810,000	154	.11
4	60°	1000 W	1,000,000	75	.24
4	60°	250 W	650,000	154	.11
4	45°	1000 W	710,000	75	.24
4	45°	250 W	460,000	154	.11
4	36°	1000 W	510,000	75	.24
4	36°	250 W	280,000	154	.11
4	30°	1000 W	440,000	75	.24
4	30°	250 W	290,000	154	.11
3.5	155°	1000 W	3,200,000	110	.16
3.5	155°	250 W	2,300,000	231	.08
3	60°	1000 W	1,800,000	145	.12
3	45°	1000 W	1,400,000	145	.12
3	30°	1000 W	900,000	145	.12
2	45°	1000 W	2,700,000	210	.09
2	30°	1000 W	1,700,000	210	.09
1	45°	1000 W	4,300,000	270	.07
1	22.5°	1000 W	2,100,000	270	.07

CHAPTER 8. EFFECTIVE LUMINOUS INTENSITIES OF RANGE LANTERNS

A. Introduction. This chapter provides tables on the effective luminous intensities for standard range lanterns, including the RL24 and RL14 range lanterns, and the 250mm lantern with condensing panels. The effective luminous intensities for the FA-240 range lantern are also provided, due to the large number of these lanterns still in service. Refer to Chapter 6 for the effective luminous intensities of omnidirectional lanterns, including the 250mm lantern with reflex reflectors, for use on ranges.

1. Table 8-1 lists the effective luminous intensities for the RL24 range lantern. The table is broken down by lens color and contact closure time. The RL24 range lantern uses the same optical drum assembly and lampchanger as the DCB24 beacon.

- The standard lamp used in the RL24 range lantern is the 120V 1000W tungsten-halogen lamp. Data for the RL24 with 120V 500W lamps are provided for those units still holding those lamps. RL24 range lanterns with 500W lamps should be converted to 1000W lamps as unit stocks of the 500W lamps are depleted.
- The color correction factors for glass cover lenses for the RL24 range lantern are: 0.22 (red), 0.20 (green). These factors were used to calculate the effective luminous intensity of the optic with colored lens installed. When acrylic filters (with standoffs) are used to provide a colored light signal, multiply the effective luminous intensity of the lantern with a clear lens times the transmission factor of the acrylic filter.

TABLE 8-1.

EFFECTIVE LUMINOUS INTENSITIES—RL24 RANGE LANTERN

Characteristic:		**Iso 2 / Fl 2.5(1)**	**Occ 4 / Iso 6**	**F**
Contact Closure Time (sec):		1.0	3.0	Fixed
Lens:	***Lamp***			
WHITE	120V 500 W	1,000,000	1,300,000	1,400,000
	1000 W	1,700,000	2,300,000	2,500,000
GREEN	120V 500 W	200,000	260,000	280,000
	1000 W	350,000	460,000	500,000
RED	120V 500 W	220,000	280,000	310,000
	1000 W	380,000	510,000	550,000

2. Tables 8-2a through 8-2f list the effective luminous intensities of the RL14 range lantern with clear cover glasses and clear spread lenses of 3°, 8°, 11°, 20°, and 28°. **Each of the following tables is for a specific color and spread lens value.**

- **The standard marine signal lamps (12V 0.25A through 3.05A) may not be used in the RL14 range lantern with a 0° spread lens.** The 12-volt CC-8 and tungsten-halogen lamps, and the 120-volt lamps may be used with any of the spread lenses, including the 0° spread lens.
- The RL14 range lantern comes with a clear, flat cover glass (0 degree lens). All other lenses must be purchased commercially from Tideland Signal Corporation.

TABLE 8-2a.

EFFECTIVE LUMINOUS INTENSITIES—RL14 RANGE LANTERN

—0 DEGREES—
—WHITE—

Characteristic:		**Q**	**Iso 2 / Fl 2.5 (1)**	**Occ 4 / Iso 6**	**F**
Contact Closure Time (sec):		0.3	1.0	3.0	Fixed
Lamp:	Beam Width				
12V 0.25 A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
0.55 A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
0.77 A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
1.15 A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
2.03 A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
3.05 A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
12V 1.0 A	1°	83,000	140,000	160,000	180,000
1.9 A	1°	100,000	200,000	240,000	260,000
3.0 A	1°	—	320,000	380,000	410,000
12V 35 W	1°	—	530,000	630,000	690,000
50 W	1°	—	600,000	760,000	820,000
75 W	1°	—	740,000	960,000	1,000,000
100 W	1°	—	920,000	1,200,000	1,300,000
110 W	1°	—	980,000	1,300,000	1,500,000
120V 150 W	1.2°	340,000	610,000	700,000	760,000
250 W	2°	290,000	590,000	700,000	750,000

TABLE 8-2b.

EFFECTIVE LUMINOUS INTENSITIES—RL14 RANGE LANTERN

—3 DEGREES—
—WHITE—

Characteristic:	**Q**	**Iso 2 / Fl 2.5 (1)**	**Occ 4 / Iso 6**	**F**
Contact Closure Time (sec):	0.3	1.0	3.0	Fixed
Lamp:				
12V 0.25 A	7,300	11,000	13,000	14,000
0.55 A	18,000	29,000	34,000	36,000
0.77 A	24,000	40,000	45,000	49,000
1.15 A	35,000	62,000	72,000	77,000
2.03 A	54,000	110,000	130,000	140,000
3.05 A	—	150,000	180,000	200,000
12V 1.0 A	29,000	50,000	58,000	62,000
1.9 A	43,000	83,000	99,000	110,000
3.0 A	—	140,000	170,000	180,000
12V 35 W	—	190,000	230,000	250,000
50 W	—	240,000	310,000	330,000
75 W	—	330,000	430,000	470,000
100 W	—	440,000	590,000	640,000
110 W	—	450,000	610,000	670,000
120V 150 W	190,000	330,000	390,000	420,000
250 W	180,000	360,000	430,000	470,000

TABLE 8-2c.

EFFECTIVE LUMINOUS INTENSITIES—RL14 RANGE LANTERN

—8 DEGREES—
—WHITE—

Characteristic:	**Q**	**Iso 2 / Fl 2.5 (1)**	**Occ 4 / Iso 6**	**F**
Contact Closure Time (sec):	0.3	1.0	3.0	Fixed
Lamp:				
12V 0.25 A	2,800	4,300	4,800	5,200
0.55 A	8,400	14,000	16,000	17,000
0.77 A	10,000	17,000	19,000	21,000
1.15 A	16,000	28,000	33,000	35,000
2.03 A	26,000	51,000	61,000	66,000
3.05 A	—	79,000	94,000	100,000
12V 1.0 A	13,000	23,000	26,000	28,000
1.9 A	20,000	39,000	46,000	50,000
3.0 A	—	65,000	78,000	85,000
12V 35 W	—	90,000	110,000	120,000
50 W	—	120,000	150,000	160,000
75 W	—	160,000	200,000	220,000
100 W	—	220,000	290,000	320,000
110 W	—	220,000	300,000	330,000
120V 150 W	100,000	180,000	210,000	230,000
250 W	110,000	220,000	260,000	280,000

TABLE 8-2d.

EFFECTIVE LUMINOUS INTENSITIES—RL14 RANGE LANTERN

—11 DEGREES—
—WHITE—

Characteristic:	**Q**	**Iso 2 / Fl 2.5 (1)**	**Occ 4 / Iso 6**	**F**
Contact Closure Time (sec):	0.3	1.0	3.0	Fixed
Lamp:				
12V 0.25 A	2,000	3,000	3,400	3,700
0.55 A	5,900	9,600	11,000	12,000
0.77 A	7,600	12,000	14,000	15,000
1.15 A	12,000	21,000	24,000	26,000
2.03 A	19,000	37,000	45,000	48,000
3.05 A	—	56,000	67,000	73,000
12V 1.0 A	11,000	20,000	23,000	24,000
1.9 A	16,000	31,000	37,000	40,000
3.0 A	—	53,000	63,000	69,000
12V 35 W	—	73,000	87,000	95,000
50 W	—	94,000	120,000	130,000
75 W	—	130,000	160,000	180,000
100 W	—	170,000	230,000	250,000
110 W	—	180,000	240,000	260,000
120V 150 W	78,000	140,000	160,000	170,000
250 W	84,000	170,000	200,000	220,000

TABLE 8-2e.

EFFECTIVE LUMINOUS INTENSITIES—RL14 RANGE LANTERN

—20 DEGREES—
—WHITE—

Characteristic:	**Q**	**Iso 2 / Fl 2.5 (1)**	**Occ 4 / Iso 6**	**F**
Contact Closure Time (sec):	0.3	1.0	3.0	Fixed
Lamp:				
12V 0.25 A	1,100	1,600	1,900	2,000
0.55 A	3,300	5,300	6,100	6,600
0.77 A	4,200	6,700	7,700	8,300
1.15 A	6,400	11,000	13,000	14,000
2.03 A	10,000	20,000	24,000	26,000
3.05 A	—	30,000	36,000	40,000
12V 1.0 A	5,100	8,800	10,000	11,000
1.9 A	7,600	15,000	18,000	19,000
3.0 A	—	25,000	30,000	33,000
12V 35 W	—	33,000	39,000	43,000
50 W	—	44,000	55,000	60,000
75 W	—	61,000	79,000	86,000
100 W	—	84,000	110,000	120,000
110 W	—	84,000	110,000	130,000
120V 150 W	41,000	73,000	85,000	91,000
250 W	44,000	89,000	110,000	110,000

TABLE 8-2f.

EFFECTIVE LUMINOUS INTENSITIES—RL14 RANGE LANTERN

—28 DEGREES—
—WHITE—

Characteristic:	**Q**	**Iso 2 / Fl 2.5 (1)**	**Occ 4 / Iso 6**	**F**
Contact Closure Time (sec):	0.3	1.0	3.0	Fixed
Lamp:				
12V 0.25 A	860	1,300	1,500	1,600
0.55 A	2,600	4,100	4,700	5,100
0.77 A	3,100	4,900	5,700	6,100
1.15 A	4,900	8,600	10,000	11,000
2.03 A	7,600	15,000	18,000	19,000
3.05 A	—	23,000	28,000	30,000
12V 1.0 A	3,900	6,600	7,600	8,200
1.9 A	5,900	11,000	14,000	15,000
3.0 A	—	20,000	23,000	25,000
12V 35 W	—	22,000	26,000	28,000
50 W	—	33,000	42,000	46,000
75 W	—	47,000	61,000	66,000
100 W	—	63,000	83,000	91,000
110 W	—	64,000	87,000	96,000
120V 150 W	32,000	57,000	66,000	71,000
250 W	35,000	71,000	85,000	91,000

3. Tables 8-3a through 8-3f list the effective luminous intensities of the RL14 range lantern with **RED** cover glasses and **RED** spread lenses of 3°, 8°, 11°, 20°, and 28° **Each of the following tables is for a specific color and spread lens value.**

- **The standard marine signal lamps (12V 0.25A through 3.05A) may not be used in the RL14 range lantern with a 0° spread lens.** The 12-volt CC-8 and tungsten-halogen lamps, and the 120-volt lamps may be used with any of the spread lenses, including the 0° spread lens.
- The RL14 range lantern comes with a clear, flat cover glass (0 degree lens). All other lenses must be purchased commercially from Tideland Signal Corporation.

TABLE 8-3a.

EFFECTIVE LUMINOUS INTENSITIES—RL14 RANGE LANTERN

—0 DEGREES—
—RED—

Characteristic:		**Q**	**Iso 2 / Fl 2.5 (1)**	**Occ 4 / Iso 6**	**F**
Contact Closure Time (sec):		0.3	1.0	3.0	Fixed
Lamp:	Beam Width				
12V 0.25 A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
0.55 A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
0.77 A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
1.15 A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
2.03 A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
3.05 A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
12V 1.0 A	1°	15,000	26,000	30,000	32,000
1.9 A	1°	19,000	37,000	44,000	47,000
3.0 A	1°	—	57,000	68,000	74,000
12V 35 W	1°	—	79,000	95,000	100,000
50 W	1°	—	90,000	110,000	120,000
75 W	1°	—	110,000	140,000	160,000
100 W	1°	—	140,000	180,000	200,000
110 W	1°	—	150,000	200,000	220,000
120V 150 W	1.2°	65,000	120,000	130,000	140,000
250 W	2°	56,000	110,000	130,000	140,000

TABLE 8-3b.

EFFECTIVE LUMINOUS INTENSITIES—RL14 RANGE LANTERN

—3 DEGREES—
—RED—

Characteristic:	**Q**	**Iso 2 / Fl 2.5 (1)**	**Occ 4 / Iso 6**	**F**
Contact Closure Time (sec):	0.3	1.0	3.0	Fixed
Lamp:				
12V 0.25 A	1,300	2,000	2,300	2,400
0.55 A	3,300	5,300	6,100	6,500
0.77 A	4,400	7,100	8,200	8,800
1.15 A	6,200	11,000	13,000	14,000
2.03 A	9,800	20,000	23,000	25,000
3.05 A	—	28,000	33,000	36,000
12V 1.0 A	5,200	8,900	10,000	11,000
1.9 A	7,700	15,000	18,000	19,000
3.0 A	—	25,000	30,000	33,000
12V 35 W	—	28,000	34,000	37,000
50 W	—	37,000	46,000	50,000
75 W	—	50,000	64,000	70,000
100 W	—	67,000	89,000	96,000
110 W	—	67,000	91,000	100,000
120V 150 W	35,000	63,000	73,000	79,000
250 W	35,000	69,000	82,000	89,000

TABLE 8-3c.

EFFECTIVE LUMINOUS INTENSITIES—RL14 RANGE LANTERN

—8 DEGREES—
—RED—

Characteristic:	**Q**	**Iso 2 / Fl 2.5 (1)**	**Occ 4 / Iso 6**	**F**
Contact Closure Time (sec):	0.3	1.0	3.0	Fixed
Lamp:				
12V 0.25 A	510	770	870	940
0.55 A	1,500	2,400	2,800	3,000
0.77 A	1,900	3,000	3,400	3,700
1.15 A	2,900	5,100	5,900	6,300
2.03 A	4,600	9,200	11,000	12,000
3.05 A	—	14,000	17,000	18,000
12V 1.0 A	2,400	4,100	4,700	5,100
1.9 A	3,600	7,000	8,300	8,900
3.0 A	—	12,000	14,000	15,000
12V 35 W	—	14,000	16,000	18,000
50 W	—	17,000	22,000	24,000
75 W	—	23,000	30,000	33,000
100 W	—	33,000	44,000	48,000
110 W	—	33,000	45,000	50,000
120V 150 W	20,000	35,000	40,000	44,000
250 W	21,000	41,000	49,000	53,000

TABLE 8-3d.

EFFECTIVE LUMINOUS INTENSITIES—RL14 RANGE LANTERN

—11 DEGREES—

—RED—

Characteristic:	**Q**	**Iso 2 / Fl 2.5 (1)**	**Occ 4 / Iso 6**	**F**
Contact Closure Time (sec):	0.3	1.0	3.0	Fixed
Lamp:				
12V 0.25 A	360	550	620	670
0.55 A	1,100	1,700	2,000	2,100
0.77 A	1,400	2,200	2,500	2,700
1.15 A	2,100	3,700	4,300	4,600
2.03 A	3,400	6,700	8,000	8,600
3.05 A	—	10,000	12,000	13,000
12V 1.0 A	2,100	3,500	4,100	4,400
1.9 A	2,900	5,600	6,600	7,100
3.0 A	—	9,500	11,000	12,000
12V 35 W	—	11,000	13,000	14,000
50 W	—	14,000	18,000	19,000
75 W	—	19,000	24,000	27,000
100 W	—	26,000	35,000	38,000
110 W	—	27,000	36,000	40,000
120V 150 W	15,000	26,000	31,000	33,000
250 W	16,000	32,000	38,000	41,000

TABLE 8-3e.

EFFECTIVE LUMINOUS INTENSITIES—RL14 RANGE LANTERN

—20 DEGREES—
—RED—

Characteristic:	**Q**	**Iso 2 / Fl 2.5 (1)**	**Occ 4 / Iso 6**	**F**
Contact Closure Time (sec):	0.3	1.0	3.0	Fixed
Lamp:				
12V 0.25 A	190	300	330	360
0.55 A	590	960	1,100	1,200
0.77 A	750	1,200	1,400	1,500
1.15 A	1,200	2,000	2,400	2,600
2.03 A	1,800	3,600	4,300	4,600
3.05 A	—	5,500	6,600	7,100
12V 1.0 A	930	1,600	1,800	2,000
1.9 A	1,400	2,700	3,200	3,400
3.0 A	—	4,500	5,400	5,900
12V 35 W	—	4,900	5,900	6,400
50 W	—	6,500	8,200	8,900
75 W	—	9,200	12,000	13,000
100 W	—	13,000	17,000	18,000
110 W	—	13,000	17,000	19,000
120V 150 W	7,800	14,000	16,000	17,000
250 W	8,400	17,000	20,000	22,000

TABLE 8-3f.

EFFECTIVE LUMINOUS INTENSITIES—RL14 RANGE LANTERN

—28 DEGREES—
—RED—

Characteristic:	**Q**	**Iso 2 / Fl 2.5 (1)**	**Occ 4 / Iso 6**	**F**
Contact Closure Time (sec):	0.3	1.0	3.0	Fixed
Lamp:				
12V 0.25 A	160	240	270	290
0.55 A	460	740	850	920
0.77 A	550	890	1,000	1,100
1.15 A	870	1,600	1,800	1,900
2.03 A	1,400	2,700	3,200	3,500
3.05 A	—	4,200	5,000	5,400
12V 1.0 A	690	1,200	1,400	1,500
1.9 A	1,100	2,100	2,500	2,600
3.0 A	—	3,500	4,200	4,600
12V 35 W	—	3,300	3,900	4,300
50 W	—	5,000	6,300	6,800
75 W	—	7,100	9,200	9,900
100 W	—	9,400	13,000	14,000
110 W	—	9,600	13,000	14,000
120V 150 W	6,100	11,000	13,000	13,000
250 W	6,700	13,000	16,000	17,000

4. Tables 8-4a through 8-4f list the effective luminous intensities of the RL14 range lantern with GREEN cover glasses and GREEN spread lenses of 3°, 8°, 11°, 20°, and 28°. **Each of the following tables is for a specific color and spread lens value.**
   - **The standard marine signal lamps (12V 0.25A through 3.05A) may not be used in the RL14 range lantern with a 0° spread lens.** The 12-volt CC-8 and tungsten-halogen lamps, and the 120-volt lamps may be used with any of the spread lenses, including the 0° spread lens.
   - The RL14 range lantern comes with a clear, flat cover glass (0 degree lens). All other lenses must be purchased commercially from Tideland Signal Corporation.

TABLE 8-4a.

EFFECTIVE LUMINOUS INTENSITIES—RL14 RANGE LANTERN

—0 DEGREES—
—GREEN—

Characteristic:		**Q**	**Iso 2 / Fl 2.5 (1)**	**Occ 4 / Iso 6**	**F**
Contact Closure Time (sec):		0.3	1.0	3.0	Fixed
Lamp:	Beam Width				
12V 0.25 A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
0.55 A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
0.77 A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
1.15 A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
2.03 A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
3.05 A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
12V 1.0 A	1°	19,000	33,000	38,000	41,000
1.9 A	1°	24,000	47,000	56,000	60,000
3.0 A	1°	—	73,000	87,000	95,000
12V 35 W	1°	—	130,000	150,000	160,000
50 W	1°	—	140,000	180,000	200,000
75 W	1°	—	180,000	230,000	250,000
100 W	1°	—	220,000	290,000	320,000
110 W	1°	—	230,000	320,000	350,000
120V 150 W	1.2°	85,000	150,000	180,000	190,000
250 W	2°	74,000	150,000	180,000	190,000

TABLE 8-4b.

EFFECTIVE LUMINOUS INTENSITIES—RL14 RANGE LANTERN

—3 DEGREES—
—GREEN—

Characteristic:	**Q**	**Iso 2 / Fl 2.5 (1)**	**Occ 4 / Iso 6**	**F**
Contact Closure Time (sec):	0.3	1.0	3.0	Fixed
Lamp:				
12V 0.25 A	1,700	2,600	2,900	3,100
0.55 A	4,200	6,700	7,700	8,300
0.77 A	5,600	9,100	10,000	11,000
1.15 A	8,000	14,000	16,000	18,000
2.03 A	12,000	25,000	30,000	32,000
3.05 A	—	35,000	42,000	46,000
12V 1.0 A	6,700	11,000	13,000	14,000
1.9 A	9,800	19,000	23,000	25,000
3.0 A	—	32,000	38,000	42,000
12V 35 W	—	45,000	54,000	59,000
50 W	—	58,000	74,000	80,000
75 W	—	79,000	100,000	110,000
100 W	—	110,000	140,000	150,000
110 W	—	110,000	150,000	160,000
120V 150 W	47,000	83,000	96,000	100,000
250 W	45,000	91,000	110,000	120,000

TABLE 8-4c.

EFFECTIVE LUMINOUS INTENSITIES—RL14 RANGE LANTERN

—8 DEGREES—
—GREEN—

Characteristic:	**Q**	**Iso 2 / Fl 2.5 (1)**	**Occ 4 / Iso 6**	**F**
Contact Closure Time (sec):	0.3	1.0	3.0	Fixed
Lamp:				
12V 0.25 A	650	980	1,100	1,200
0.55 A	1,900	3,100	3,600	3,900
0.77 A	2,400	3,800	4,400	4,700
1.15 A	3,600	6,500	7,500	8,100
2.03 A	5,900	12,000	14,000	15,000
3.05 A	—	18,000	22,000	23,000
12V 1.0 A	3,100	5,200	6,100	6,500
1.9 A	4,600	8,900	11,000	11,000
3.0 A	—	15,000	18,000	20,000
12V 35 W	—	22,000	26,000	28,000
50 W	—	28,000	35,000	38,000
75 W	—	37,000	48,000	53,000
100 W	—	53,000	70,000	77,000
110 W	—	54,000	73,000	80,000
120V 150 W	26,000	46,000	53,000	57,000
250 W	27,000	55,000	65,000	70,000

TABLE 8-4d.

EFFECTIVE LUMINOUS INTENSITIES—RL14 RANGE LANTERN

—11 DEGREES—
—GREEN—

Characteristic:	**Q**	**Iso 2 / Fl 2.5 (1)**	**Occ 4 / Iso 6**	**F**
Contact Closure Time (sec):	0.3	1.0	3.0	Fixed
Lamp:				
12V 0.25 A	460	700	790	850
0.55 A	1,400	2,200	2,500	2,700
0.77 A	1,700	2,800	3,300	3,500
1.15 A	2,700	4,700	5,500	5,900
2.03 A	4,300	8,600	10,000	11,000
3.05 A	—	13,000	15,000	17,000
12V 1.0 A	2,600	4,500	5,200	5,600
1.9 A	3,700	7,100	8,500	9,100
3.0 A	—	12,000	15,000	16,000
12V 35 W	—	18,000	21,000	23,000
50 W	—	23,000	28,000	31,000
75 W	—	30,000	39,000	43,000
100 W	—	42,000	55,000	60,000
110 W	—	42,000	58,000	63,000
120V 150 W	19,000	35,000	40,000	43,000
250 W	21,000	42,000	50,000	54,000

TABLE 8-4e.

EFFECTIVE LUMINOUS INTENSITIES—RL14 RANGE LANTERN

—20 DEGREES—
—GREEN—

Characteristic:	**Q**	**Iso 2 / Fl 2.5 (1)**	**Occ 4 / Iso 6**	**F**
Contact Closure Time (sec):	0.3	1.0	3.0	Fixed
Lamp:				
12V 0.25 A	250	380	430	460
0.55 A	760	1,200	1,400	1,500
0.77 A	950	1,500	1,800	1,900
1.15 A	1,500	2,600	3,000	3,300
2.03 A	2,300	4,600	5,500	5,900
3.05 A	—	7,000	8,400	9,100
12V 1.0 A	1,200	2,000	2,300	2,500
1.9 A	1,700	3,400	4,000	4,300
3.0 A	—	5,800	6,900	7,500
12V 35 W	—	7,900	9,400	10,000
50 W	—	10,000	13,000	14,000
75 W	—	15,000	19,000	21,000
100 W	—	20,000	27,000	29,000
110 W	—	20,000	27,000	30,000
120V 150 W	10,000	18,000	21,000	23,000
250 W	11,000	22,000	27,000	29,000

TABLE 8-4f.

EFFECTIVE LUMINOUS INTENSITIES—RL14 RANGE LANTERN

—28 DEGREES—
—GREEN—

Characteristic:	**Q**	**Iso 2 / Fl 2.5 (1)**	**Occ 4 / Iso 6**	**F**
Contact Closure Time (sec):	0.3	1.0	3.0	Fixed
Lamp:				
12V 0.25 A	200	300	340	370
0.55 A	590	950	1,100	1,200
0.77 A	700	1,100	1,300	1,400
1.15 A	1,100	2,000	2,300	2,500
2.03 A	1,700	3,500	4,100	4,500
3.05 A	—	5,300	6,300	6,900
12V 1.0 A	890	1,500	1,800	1,900
1.9 A	1,300	2,600	3,100	3,400
3.0 A	—	4,500	5,400	5,900
12V 35 W	—	5,200	6,300	6,800
50 W	—	8,000	10,000	11,000
75 W	—	11,000	15,000	16,000
100 W	—	15,000	20,000	22,000
110 W	—	15,000	21,000	23,000
120V 150 W	8,000	14,000	17,000	18,000
250 W	8,900	18,000	21,000	23,000

5. Table 8-5 lists the effective luminous intensities of the 250mm lantern, with condensing panels. The table is broken down by lens cover color, lamp size, and contact closure time. Refer to Chapter 6, Effective Luminous Intensities of Omnidirectional Lanterns, for limitations on lamp size and power dissipation.

   - The tabulated values are intensities at the center of the beam created by the condensing panel. The full width (to 50% intensity) of the beam is 1.5 degrees.
   - At ±3 degrees of the beam axis, the intensities fall to 150% of the standard values for a 250mm lantern, as listed in Table 6-3.
   - From 3 degrees to 30 degrees on either side of the beam axis, the intensities fall to 50% of the standard values for a 250mm lantern, as listed in Table 6-3.
   - When a reflex reflector is used opposite of the condensing panel, increase the listed intensities by 20 percent.

TABLE 8-5.

EFFECTIVE LUMINOUS INTENSITIES—250MM LANTERN (WITH CONDENSING PANEL)

Lens	Lamp	CONTACT CLOSURE TIME (seconds)			
		0.3	1	3	Fixed
		Effective Luminous Intensity (candela)			
Clear	12V 0.25A	460	700	790	850
	0.55A	900	1,500	1,700	1,800
	0.77A	2,000	3,200	3,700	4,000
	1.15A	2,500	4,400	5,100	5,500
	2.03A	3,500	7,000	8,400	9,000
	3.05A	—	8,500	10,000	11,000
	120V 250W	20,000	39,000	47,000	50,000
Yellow	12V 0.25A	330	490	560	600
	0.55A	630	1,000	1,200	1,300
	0.77A	1,400	2,300	2,600	2,800
	1.15A	1,800	3,100	3,600	3,900
	2.03A	2,500	5,000	5,900	6,400
	3.05A	—	6,000	7,200	7,800
	120V 250W	14,000	28,000	33,000	36,000
Red and Green	12V 0.25A	140	220	250	260
	0.55A	280	450	520	560
	0.77A	620	1,000	1,100	1,200
	1.15A	770	1,400	1,600	1,700
	2.03A	1,100	2,200	2,600	2,800
	3.05A	—	2,600	3,100	3,400
	120V 250W	6,000	12,000	14,000	16,000

6. Tables 8-6a through 8-6d list the effective luminous intensities of the FA-240 range lantern. Each table covers a specific color (white, red, green, and yellow) and is broken down by spread lens rating (3.5°, 8°, and 30°), lamp size, and contact closure time. FA-240 range lanterns may be used as long as they remain serviceable, but are not considered standard equipment for new installations.

- The tabulated values are intensities at the center of the beam created by the spread lens. The full width (to 50% intensity) of the beam is indicated by the spread lens rating.
- The FA-240 requires precision leveling and sighting. The lantern must be removed from service and focused in a shop facility when pre-selected lamps are exhausted.

TABLE 8-6a.

EFFECTIVE LUMINOUS INTENSITIES—FA-240 RANGE LANTERN

—WHITE—

Lens	Lamp	CONTACT CLOSURE TIME (seconds)			
		0.3	1	3	Fixed
		Effective Luminous Intensity (candela)			
3.5°	12V 0.25A	1,300	2,000	2,300	2,500
	0.55A	2,900	4,700	5,400	5,800
	0.77A	5,200	8,300	9,600	10,000
	1.15A	6,400	11,000	13,000	14,000
	2.03A	12,000	24,000	29,000	31,000
8°	12V 0.25A	770	1,200	1,300	1,420
	0.55A	1,700	2,700	3,100	3,300
	0.77A	3,100	5,100	5,800	6,300
	1.15A	3,900	7,000	8,100	8,700
	2.03A	6,900	14,000	17,000	18,000
30°	12V 0.25A	180	280	320	340
	0.55A	400	650	740	800
	0.77A	750	1,200	1,400	1,500
	1.15A	970	1,700	2,000	2,200
	2.03	1,700	3,500	4,200	4,500

TABLE 8-6b.

EFFECTIVE LUMINOUS INTENSITIES—FA-240 RANGE LANTERN

—RED—

Lens	Lamp	CONTACT CLOSURE TIME (seconds)			
		0.3	1	3	Fixed
		Effective Luminous Intensity (candela)			
3.5°	12V 0.25A	440	670	760	820
	0.55A	950	1,500	1,800	1,900
	0.77A	1,700	2,800	3,200	3,400
	1.15A	2,100	3,800	4,400	4,700
	2.03A	4,000	7,900	9,400	10,000
8°	12V 0.25A	250	380	440	470
	0.55A	540	880	1,000	1,100
	0.77A	1,000	1,700	1,900	2,100
	1.15A	1,300	2,300	2,700	2,900
	2.03A	2,300	4,600	5,500	5,900
30°	12V 0.25A	60	92	100	110
	0.55A	130	210	250	260
	0.77A	250	400	460	500
	1.15A	320	570	660	710
	2.03	580	1,200	1,400	1,500

TABLE 8-6c.

EFFECTIVE LUMINOUS INTENSITIES—FA-240 RANGE LANTERN

—GREEN—

Lens	Lamp	CONTACT CLOSURE TIME (seconds)			
		0.3	1	3	Fixed
		Effective Luminous Intensity (candela)			
3.5°	12V 0.25A	370	570	640	690
	0.55A	810	1,300	1,500	1,600
	0.77A	1,400	2,300	2,700	2,900
	1.15A	1,800	3,200	3,700	4,000
	2.03A	3,400	6,700	8,000	8,600
8°	12V 0.25A	210	330	370	400
	0.55A	460	750	860	920
	0.77A	880	1,400	1,600	1,800
	1.15A	1,100	1,900	2,300	2,400
	2.03A	1,900	3,900	4,600	5,000
30°	12V 0.25A	51	78	89	95
	0.55A	110	180	210	220
	0.77A	210	340	390	420
	1.15A	270	480	660	600
	2.03	490	980	1,200	1,300

TABLE 8-6d.

EFFECTIVE LUMINOUS INTENSITIES—FA-240 RANGE LANTERN

—YELLOW—

Lens	Lamp	CONTACT CLOSURE TIME (seconds)			
		0.3	1	3	Fixed
		Effective Luminous Intensity (candela)			
3.5°	12V 0.25A	1,100	1,600	1,800	2,000
	0.55A	2,300	3,700	4,300	4,600
	0.77A	4,100	6,700	7,700	8,200
	1.15A	5,100	9,200	11,000	11,000
	2.03A	9,600	19,000	23,000	25,000
8°	12V 0.25A	610	930	1,100	1,100
	0.55A	1,300	2,100	2,500	2,600
	0.77A	2,500	4,100	4,700	5,000
	1.15A	3,100	5,600	6,500	7,000
	2.03A	5,600	11,000	13,000	14,000
30°	12V 0.25A	150	220	250	270
	0.55A	320	520	600	640
	0.77A	600	970	1,100	1,200
	1.15A	770	1,400	1,600	1,700
	2.03	1,400	2,800	3,300	3,600

APPENDIX A . VISIBILITY AND TRANSMISSIVITY VALUES

1. In 1988, the U.S. Coast Guard Research and Development Center studied several years of National Weather Service coastal visibility data in order to update the values of visibility and transmissivity used for aid-to-navigation planning along the coastal U.S. and Great Lakes. The following tables provide these updated values for 80 and 90 percent of the time.

2. The tables, in order, are for Alaska (4 pages), Hawaii (1 page), the West Coast (2 pages), the Great Lakes (2 pages), the East Coast (2 pages), and Florida & the Gulf Coasts (2 pages). The values are presented in one-degree grids for each of these regions. To find the visibility value, enter the appropriate table using the whole number degree of latitude and longitude for the position of the aid. For example, for an aid located at 39° 20.9' N 123° 49.6' W, enter the table at "LAT 39 LONG 123." Note, the values provided in the following tables are based on averaging the data collected within each one-degree grid over a 30 year period. The values are valid for all sections of the one-degree grid. Therefore, interpolation between adjacent grids should not be performed.

3. All visibility values are in nautical miles (nm).

ALASKA

LAT	LONG	V(80%)	T(80%)	V(90%)	T(90%)
51	172	3.1	0.38	—	—
51	173	3.2	0.39	—	—
51	174	3.3	0.41	—	—
52	167	3.9	0.47	1.4	0.12
52	168	4.1	0.48	1.5	0.14
52	169	3.9	0.47	1.3	0.11
52	170	3.7	0.45	—	—
52	171	2.7	0.32	—	—
52	172	4.3	0.50	1.8	0.19
52	173	4.7	0.53	2.6	0.31
52	174	4.6	0.52	2.4	0.28
53	165	4.9	0.54	2.1	0.24
53	166	4.9	0.54	2.7	0.33
53	167	5.2	0.56	2.8	0.34
53	168	5.2	0.56	3.0	0.36
53	169	4.5	0.52	2.2	0.25
54	131	5.2	0.56	2.4	0.28
54	132	5.2	0.56	2.5	0.31
54	133	4.8	0.54	2.5	0.30
54	161	4.6	0.52	2.2	0.26
54	162	4.8	0.54	2.3	0.28
54	163	4.3	0.50	1.7	0.18
54	164	3.9	0.47	1.5	0.14
54	165	4.1	0.48	1.9	0.21
54	166	4.3	0.50	2.1	0.24
54	167	4.1	0.48	1.9	0.21
55	129	5.4	0.57	3.3	0.41
55	130	5.4	0.57	3.3	0.41
55	131	5.4	0.57	3.3	0.41
55	132	5.8	0.60	3.1	0.38
55	133	5.6	0.58	2.9	0.36
55	158	6.6	0.64	3.8	0.46
55	159	6.2	0.62	3.5	0.43
55	160	5.8	0.59	3.6	0.43
55	161	6.0	0.61	3.8	0.45
55	162	3.6	0.44	1.0	0.05

ALASKA

LAT	LONG	V(80%)	T(80%)	V(90%)	T(90%)
55	163	3.3	0.40	—	—
55	164	3.8	0.45	1.4	0.12
56	131	6.3	0.62	4.1	0.48
56	132	6.3	0.62	4.1	0.48
56	133	6.6	0.64	3.8	0.46
56	134	5.8	0.60	3.6	0.43
56	135	5.9	0.60	3.3	0.40
56	152	6.2	0.62	3.3	0.40
56	153	5.8	0.60	3.3	0.40
56	154	5.3	0.57	2.8	0.35
56	155	5.9	0.60	3.2	0.39
56	156	6.5	0.63	3.8	0.46
56	157	6.8	0.64	4.2	0.49
56	158	5.2	0.56	2.4	0.29
56	159	4.7	0.53	2.4	0.28
56	160	3.5	0.43	—	—
56	161	2.5	0.29	—	—
56	162	3.5	0.43	—	—
57	132	4.3	0.50	1.9	0.21
57	133	4.3	0.50	1.9	0.21
57	134	6.6	0.64	4.4	0.51
57	135	5.6	0.58	3.5	0.43
57	136	6.0	0.61	3.7	0.44
57	152	6.0	0.61	3.3	0.41
57	153	6.9	0.65	4.3	0.50
57	154	8.0	0.69	5.7	0.59
57	155	7.3	0.66	4.9	0.55
57	156	5.7	0.59	2.7	0.34
57	157	3.8	0.45	1.5	0.13
57	158	3.8	0.45	1.5	0.13
58	133	2.6	0.31	1.0	0.06
58	134	2.6	0.31	1.0	0.06
58	135	7.1	0.65	4.8	0.53
58	136	5.9	0.60	3.6	0.44
58	137	6.2	0.61	3.7	0.45
58	138	6.1	0.61	3.7	0.44
58	151	6.7	0.64	4.1	0.48
58	152	6.0	0.60	3.5	0.43

ALASKA

LAT	LONG	V(80%)	T(80%)	V(90%)	T(90%)
58	153	7.7	0.68	5.1	0.56
58	154	7.7	0.68	5.1	0.56
58	156	6.7	0.64	4.6	0.52
58	157	6.7	0.64	4.6	0.52
58	158	6.7	0.64	4.6	0.52
58	159	3.4	0.41	—	—
58	160	3.4	0.41	—	—
58	161	1.2	0.08	—	—
58	162	4.9	0.54	2.5	0.30
58	163	1.0	0.06	—	—
59	136	5.9	0.60	3.6	0.44
59	137	6.2	0.61	3.7	0.45
59	138	6.7	0.64	4.1	0.48
59	139	6.7	0.64	4.1	0.48
59	140	6.9	0.65	4.5	0.52
59	141	6.0	0.61	3.6	0.43
59	142	6.3	0.62	3.7	0.45
59	143	6.8	0.64	4.1	0.48
59	144	6.6	0.64	4.0	0.47
59	145	6.6	0.63	4.0	0.48
59	146	6.8	0.65	4.3	0.50
59	147	6.3	0.62	3.8	0.46
59	148	7.1	0.66	4.1	0.48
59	149	7.3	0.66	4.5	0.5
59	150	6.0	0.60	3.6	0.43
59	151	6.9	0.65	4.0	0.47
59	152	8.2	0.69	5.2	0.56
59	153	7.8	0.68	4.9	0.55
59	154	7.8	0.68	4.9	0.55
59	156	6.7	0.64	4.6	0.52
59	158	6.7	0.64	4.6	0.52
59	160	3.4	0.41	—	—
59	161	1.2	0.08	—	—
59	162	4.9	0.54	2.5	0.30
59	163	2.3	0.27	—	—
59	164	2.3	0.27	—	—
59	165	1.8	0.18	—	—
59	166	5.5	0.58	1.8	0.18

LAT	LONG	V(80%)	T(80%)	V(90%)	T(90%)
59	167	2.0	0.22	—	—
59	168	—	—	—	—
60	141	6.0	0.61	3.6	0.43
60	142	6.3	0.62	3.7	0.45
60	143	6.8	0.64	4.1	0.48
60	144	2.5	0.30	—	—
60	145	5.6	0.58	3.2	0.39
60	146	6.1	0.61	3.6	0.43
60	147	6.0	0.61	3.7	0.45
60	161	1.2	0.08	—	—
60	162	4.9	0.54	2.5	0.30
61	146	6.1	0.61	3.6	0.43
61	147	6.0	0.61	3.7	0.45
61	148	4.7	0.53	1.7	0.18
61	149	3.1	0.38	1.4	0.11
61	150	10.6	0.75	8.1	0.69
61	152	9.0	0.72	5.9	0.60
61	164	3.8	0.46	—	—
61	167	3.9	0.47	1.3	0.10
61	168	1.7	0.17	—	—
62	166	6.5	0.63	3.1	0.38
62	167	4.7	0.53	2.4	0.29
63	163	9.3	0.72	6.7	0.64
64	164	8.7	0.71	5.9	0.60
64	167	3.6	0.44	—	—
64	168	2.8	0.34	—	—
65	166	6.5	0.63	3.8	0.45
65	167	4.7	0.53	2.0	0.22
65	168	2.7	0.33	—	—
66	166	7.3	0.66	4.7	0.53
66	167	4.8	0.54	3.0	0.37
66	168	3.7	0.44	—	—
67	164	7.0	0.65	4.5	0.51
68	166	5.5	0.58	3.4	0.41
68	167	4.6	0.52	—	—
69	163	5.6	0.59	3.3	0.40
69	167	3.9	0.46	1.6	0.15

HAWAII

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LAT	LONG	V(80%)	T(80%)	V(90%)	T(90%)
18	154	11.4	0.77	8.7	0.71
18	155	10.9	0.76	8.6	0.71
18	156	11.1	0.76	8.8	0.71
18	157	10.7	0.76	8.9	0.71
18	158	10.9	0.76	8.4	0.70
18	159	9.5	0.73	8.1	0.69
18	160	10.4	0.75	8.3	0.70
19	154	9.1	0.72	7.2	0.66
19	155	9.1	0.72	6.9	0.65
19	156	10.4	0.75	8.1	0.69
19	157	10.3	0.75	8.2	0.69
19	158	10.0	0.74	8.4	0.70
19	159	10.0	0.74	8.0	0.69
19	160	11.3	0.77	8.5	0.70
20	154	10.1	0.74	7.9	0.68
20	155	11.2	0.77	8.3	0.70
20	156	10.6	0.75	8.9	0.72
20	157	10.0	0.74	8.8	0.71
20	158	10.3	0.75	8.9	0.71
20	159	12.6	0.79	9.9	0.74
20	160	11.9	0.78	9.4	0.73
21	154	11.6	0.77	9.2	0.72
21	155	11.4	0.77	9.3	0.72
21	156	11.5	0.77	9.5	0.73
21	157	9.7	0.73	8.2	0.69
21	158	11.2	0.76	9.2	0.72
21	159	11.5	0.77	9.6	0.73
21	160	11.4	0.77	9.3	0.72
22	154	12.1	0.78	9.8	0.74
22	155	13.0	0.79	10.4	0.75
22	156	11.0	0.76	9.2	0.72
22	157	11.1	0.76	9.2	0.72
22	158	11.2	0.77	9.2	0.72
22	159	10.8	0.76	9.0	0.72
22	160	11.3	0.77	9.2	0.72

WEST COAST

LAT	LONG	V(80%)	T(80%)	V(90%)	T(90%)
32	116	7.0	0.65	5.2	0.56
33	117	5.4	0.58	3.6	0.43
33	118	6.7	0.64	4.8	0.54
33	119	7.4	0.67	5.5	0.58
33	120	8.1	0.69	6.0	0.61
34	118	4.0	0.47	1.8	0.19
34	119	3.8	0.46	2.1	0.24
34	120	6.7	0.64	4.2	0.49
34	121	7.6	0.67	5.3	0.57
35	120	6.7	0.64	3.8	0.45
35	121	7.2	0.66	4.8	0.53
35	122	7.0	0.65	4.7	0.53
36	121	6.7	0.64	4.2	0.49
36	122	6.9	0.65	4.4	0.51
37	122	5.4	0.58	2.7	0.33
37	123	6.1	0.61	3.2	0.39
38	122	4.2	0.49	2.6	0.32
38	123	6.0	0.61	2.9	0.36
38	124	6.9	0.65	4.2	0.49
39	123	6.4	0.62	3.3	0.40
39	124	6.6	0.63	3.5	0.42
40	124	6.0	0.61	2.8	0.34
40	125	7.4	0.67	4.5	0.51
41	124	6.7	0.64	3.4	0.41
41	125	7.3	0.66	4.4	0.51
42	124	6.4	0.63	3.2	0.40
42	125	7.1	0.66	3.9	0.47
43	124	6.7	0.64	3.3	0.41
43	125	7.3	0.66	4.5	0.51
44	123	7.1	0.66	4.2	0.49
44	124	7.1	0.66	4.2	0.49
44	125	7.4	0.67	4.6	0.52
45	123	7.3	0.66	4.5	0.52
45	124	7.5	0.67	4.9	0.54
45	125	7.5	0.67	5.1	0.55

WEST COAST

LAT	LONG	V(80%)	T(80%)	V(90%)	T(90%)
46	123	6.9	0.65	4.2	0.49
46	124	7.1	0.66	4.5	0.52
46	125	7.2	0.66	4.9	0.54
47	122	4.4	0.50	2.4	0.29
47	123	7.1	0.66	4.3	0.50
47	124	7.3	0.66	4.4	0.51
47	125	6.6	0.63	4.2	0.49
48	122	5.6	0.58	3.8	0.45
48	123	4.9	0.55	—	—
48	124	6.1	0.61	3.5	0.42
48	125	5.5	0.58	2.6	0.32
49	122	3.8	0.45	—	—
49	124	3.7	0.45	—	—
49	125	4.5	0.51	2.1	0.24

GREAT LAKES

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LAT	LONG	V(80%)	T(80%)	V(90%)	T(90%)
41	80	4.5	0.52	2.6	0.32
41	81	6.4	0.62	4.0	0.47
41	82	6.6	0.63	4.3	0.50
41	83	5.6	0.58	3.1	0.38
41	86	6.8	0.65	4.3	0.50
41	87	6.8	0.65	4.3	0.50
42	79	5.9	0.60	3.5	0.43
42	80	5.1	0.56	2.9	0.35
42	81	5.9	0.60	3.6	0.43
42	82	4.0	0.47	2.3	0.27
42	83	5.3	0.57	3.2	0.39
42	86	5.8	0.59	3.1	0.38
42	87	6.6	0.64	3.6	0.44
43	76	5.8	0.60	3.2	0.39
43	77	5.5	0.58	2.9	0.36
43	78	5.1	0.56	2.5	0.30
43	79	4.5	0.51	2.4	0.29
43	81	4.7	0.53	3.1	0.38
43	82	6.6	0.63	3.8	0.46
43	83	6.6	0.64	3.5	0.42
43	86	6.2	0.62	3.1	0.38
43	87	6.5	0.63	3.2	0.39
44	80	4.6	0.52	2.7	0.32
44	81	4.2	0.49	2.0	0.23
44	82	6.5	0.63	3.3	0.40
44	83	7.4	0.67	4.1	0.49
44	86	6.6	0.64	3.2	0.40
44	87	7.2	0.66	3.6	0.44
45	80	4.9	0.54	2.5	0.30
45	81	5.2	0.56	2.2	0.26
45	82	6.0	0.61	2.6	0.32
45	83	7.1	0.66	4.4	0.50
45	84	6.1	0.61	3.0	0.37
45	86	7.6	0.67	4.0	0.48
45	87	7.4	0.67	4.1	0.48

GREAT LAKES

LAT	LONG	V(80%)	T(80%)	V(90%)	T(90%)
46	81	4.8	0.54	2.6	0.32
46	82	5.8	0.60	3.1	0.38
46	83	4.9	0.55	2.6	0.32
46	84	6.1	0.61	3.0	0.37
46	85	7.2	0.66	3.3	0.40
46	86	7.4	0.67	3.9	0.46
46	87	7.2	0.66	2.2	0.26
46	88	8.0	0.69	3.3	0.40
46	89	8.2	0.69	3.6	0.43
46	90	8.8	0.71	4.5	0.51
46	91	8.5	0.70	4.2	0.49
47	84	6.2	0.62	1.7	0.18
47	85	6.2	0.62	1.7	0.18
47	86	6.3	0.62	1.2	0.08
47	87	7.2	0.66	2.2	0.26
47	88	8.0	0.69	3.3	0.40
47	89	8.2	0.69	3.6	0.43
47	90	8.8	0.71	4.5	0.51
47	91	8.4	0.70	3.7	0.44
48	85	5.1	0.55	1.4	0.11
48	86	5.1	0.55	1.4	0.11
48	87	6.5	0.63	1.4	0.11
48	88	7.9	0.68	3.4	0.42
48	89	6.5	0.63	3.9	0.46

EAST COAST NORTH OF FLORIDA

LAT	LONG	V(80%)	T(80%)	V(90%)	T(90%)
31	80	9.2	0.72	7.4	0.67
31	81	9.0	0.72	7.7	0.68
32	79	8.7	0.71	6.8	0.65
32	80	8.0	0.69	6.5	0.63
32	81	8.0	0.69	6.5	0.63
33	77	9.4	0.73	7.3	0.66
33	78	8.9	0.71	6.8	0.64
33	79	8.9	0.71	6.8	0.64
34	75	9.5	0.73	7.3	0.66
34	76	7.8	0.68	6.1	0.61
34	77	6.3	0.62	4.9	0.54
35	75	8.0	0.69	5.8	0.60
35	76	8.0	0.69	5.8	0.60
35	77	8.0	0.69	5.8	0.60
36	75	6.9	0.65	5.1	0.55
36	76	6.0	0.61	4.5	0.51
37	74	7.2	0.66	5.3	0.57
37	75	6.5	0.63	4.7	0.53
37	76	5.5	0.58	3.9	0.47
37	77	5.5	0.58	3.4	0.42
38	74	6.6	0.63	4.3	0.49
38	75	6.0	0.61	4.0	0.47
38	76	6.1	0.61	4.4	0.50
38	77	6.1	0.61	4.4	0.50
39	73	6.4	0.62	4.0	0.48
39	74	6.2	0.61	3.9	0.47
39	75	5.6	0.58	3.6	0.44
39	76	5.2	0.56	3.2	0.40
40	71	5.4	0.58	3.0	0.37
40	72	5.9	0.60	3.5	0.43
40	73	5.5	0.58	3.1	0.38
40	74	4.3	0.50	2.4	0.29
40	75	5.6	0.58	3.6	0.44
41	69	4.2	0.49	—	—
41	70	5.2	0.56	2.6	0.31
41	71	4.4	0.51	1.9	0.21

EAST COAST NORTH OF FLORIDA

LAT	LONG	V(80%)	T(80%)	V(90%)	T(90%)
41	72	4.4	0.50	2.4	0.28
41	73	4.0	0.47	1.4	0.12
42	69	5.5	0.58	2.5	0.30
42	70	5.9	0.60	3.3	0.40
42	71	4.0	0.47	2.2	0.26
43	67	1.7	0.17	—	—
43	68	5.0	0.55	1.3	0.09
43	69	5.5	0.58	2.4	0.28
43	70	5.4	0.57	2.5	0.30
44	66	3.3	0.41	—	—
44	67	2.3	0.28	—	—
44	68	—	—	—	—
44	69	3.7	0.44	—	—

FLORIDA AND GULF COAST

LAT	LONG	V(80%)	T(80%)	V(90%)	T(90%)
24	79	10.9	0.76	9.3	0.72
24	80	11.0	0.76	9.1	0.72
24	81	12.1	0.78	9.8	0.74
24	82	12.1	0.78	9.8	0.74
25	79	12.0	0.78	9.8	0.74
25	80	11.9	0.78	9.6	0.73
25	81	9.6	0.73	7.6	0.67
25	82	9.7	0.73	8.0	0.69
26	79	12.2	0.78	9.8	0.74
26	80	11.1	0.76	8.7	0.71
26	81	12.3	0.78	9.8	0.74
26	82	12.2	0.78	9.8	0.74
26	96	9.0	0.72	6.9	0.65
26	97	7.9	0.69	5.3	0.57
27	80	11.0	0.76	8.9	0.71
27	82	10.0	0.74	7.6	0.67
27	95	10.5	0.75	8.1	0.69
27	96	8.8	0.71	6.7	0.64
27	97	6.8	0.64	4.2	0.49
28	80	10.9	0.76	8.7	0.71
28	82	8.7	0.71	6.4	0.63
28	85	9.9	0.74	8.2	0.69
28	88	10.8	0.76	8.5	0.70
28	89	9.9	0.74	7.5	0.67
28	90	10.6	0.75	8.1	0.69
28	91	10.9	0.76	8.3	0.70
28	92	10.4	0.75	8.0	0.69
28	93	9.9	0.74	7.5	0.67
28	94	8.8	0.71	6.6	0.64
28	95	8.7	0.71	6.3	0.62
28	96	8.7	0.71	6.3	0.62
29	80	9.3	0.73	7.7	0.68
29	81	8.5	0.70	6.3	0.62
29	82	9.1	0.72	7.5	0.67
29	83	10.3	0.75	8.2	0.69
29	84	6.9	0.65	3.8	0.46

FLORIDA AND GULF COAST

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LAT	LONG	V(80%)	T(80%)	V(90%)	T(90%)
29	85	8.7	0.71	6.8	0.64
29	86	8.6	0.71	6.9	0.65
29	87	8.6	0.71	6.8	0.64
29	88	9.2	0.72	6.7	0.64
29	89	7.3	0.66	4.5	0.52
29	90	10.0	0.74	6.3	0.62
29	91	9.5	0.73	7.4	0.67
29	92	10.1	0.74	7.5	0.67
29	93	9.3	0.72	6.7	0.64
29	94	8.6	0.71	6.1	0.61
29	95	8.6	0.71	6.1	0.61
30	80	8.4	0.70	6.9	0.65
30	81	7.9	0.68	6.3	0.62
30	84	9.3	0.72	7.1	0.66
30	85	8.7	0.71	6.8	0.64
30	86	8.6	0.71	6.9	0.65
30	87	8.3	0.70	6.4	0.63
30	88	8.4	0.70	6.5	0.63
30	89	7.3	0.66	4.5	0.52
31	80	9.2	0.72	7.4	0.67
31	81	9.0	0.72	7.7	0.68

APPENDIX B . EXAMPLES OF APPLIED PROCEDURES FOR CHOOSING OPTICAL SYSTEMS

1. General Application of Allard's Law.

Example: Consider a buoy located in the Thames River at New London, Connecticut. The buoy is equipped with a 155mm red lens and 12-volt, 2.03A lamps. The flash characteristic is one red flash every 6 seconds. Background lighting is negligible. What is the luminous range of the light for 80 percent of the nights?

Solution: The flash characteristic is one red flash every 6 seconds. This is a standard flash characteristic produced by the CG 181 flasher. From Table 5-1, the contact closure time for a Fl 6(0.6) is 0.6 seconds. From Table 6-1, the effective luminous intensity of the 155mm optic with a 2.03A lamp, red lens, and 0.6 second contact closure time is 100 candela. Background lighting is negligible; so the threshold of illuminance equals 0.67 sea-mile candela. The buoy's approximate location is 41°N, 072°W. From Appendix A, the visibility for 80 percent of the nights of the year is 4.4 nm or greater.

Use Allard's Law (equation 2-7) to determine the luminous range of the light:

$$I_e = \frac{E * D^2}{(0.05)^{\frac{D}{V}}},$$

where:

- $E = 0.67$ sea-mile candela for no background lighting;
- $I_e = 100$ candelas from Table 6-1; and
- $V = 4.4$ nm from Appendix A.

The equation can not be solved directly; an iterative technique must be used. When solved, the luminous range D is approximately 3.6 nautical miles. This means that for 80 percent of the nights of the year, the light can be detected at a range of 3.6 nautical miles or greater.

Example: On Kodiak Island, Alaska, a major light is to be installed as an aid to navigation to vessels operating in the Gulf of Alaska. The operational requirement is for a light that is visible at a range of 12 nautical miles on 90 percent of the nights. What is the effective luminous intensity required for the light?

Solution: Assume no background lighting, so the threshold of illuminance, E, equals 0.67 sea-mile candela. The desired luminous range, D, equals 12 nautical miles. The location of the light is approximately 57°N, 152°W. From Appendix A, the visibility, V, for the aid's location on 90 percent of the nights is 3.3 nm or greater. Use Allard's Law (equation 2-7) to solve for the effective luminous intensity, I_e:

$$I_e = \frac{E * D^2}{(0.05)^{\frac{D}{V}}},$$

The effective luminous intensity, I_e, is approximately 5,200,000 candela. This intensity is, of course, not practical using Coast Guard standard optics. The operational requirement will need to be re-evaluated.

2. Selecting an Optic for a Buoy.

Example: In conducting a Waterway Analysis Management System (WAMS) study of approaches to Norfolk Harbor, a new buoy is required to mark the turn from Thimble Shoal Channel to the Hampton Roads Bridge Tunnel. An 8 x 26 LBR buoy will be used, and the buoy should pass down the port side of a vessel entering the harbor from seaward. The buoy must be visible at a range of 3 nautical miles for 80 percent of the nights. Select lens/lamp combinations that meet the operational requirement.

Solution: The operational requirement is for a light that can be detected at a luminous range of 3 nautical miles for 80 percent of the nights. Because the buoy will pass down the port side of a vessel, the lens color must be green. The buoy will mark a turn in the channel; therefore, the flash characteristic is chosen as "quick flash." Table 5-1 lists the contact closure time for a quick-flash light as 0.3 seconds. Background lighting is minimal; therefore, the threshold of illuminance, E, is 0.67 sea-mile candela. The approximate location of the buoy is 36°59' N, 076°15' W. For the given latitude and longitude, Appendix A lists the visibility as 6.0 nm for 80 percent of the nights. (Remember to round the latitude and longitude DOWN to whole degrees for entering the tables in Appendix A.)

Use Allard's Law (equation 2-7) to calculate the effective luminous intensity:

$$I_e = \frac{E * D^2}{(0.05)^{\frac{D}{V}}},$$

where:

- E = 0.67 sea-mile candela for no background lighting;
- D = 3 nm, as the operational requirement; and
- V = 6.0 nm from Appendix A.

Solving Allard's Law yields approximately 27 candela as the required effective luminous intensity to meet the operational requirement.

Enter Table 6-1, using 0.3 seconds for the contact closure time and green for the color of the lens. The 12V, 0.77A lamp (or larger) will produce an effective intensity exceeding 27 candela. Thus, the 155mm lantern with a 12VDC, 0.77A lamp is the correct optic to select to meet the operational requirement.

3. Selecting an Optic for a Fixed Minor Aid.

Example: In the Inland Waterway in North Carolina, a minor light needs to be mounted on a multiple-pile wooden structure located in the water. Background lighting is minor. The desired luminous range is 3 nautical miles for 80 percent of the nights. The characteristic is a red flash every 4 seconds. To maintain simplicity, a rotating beacon is not desired. Commercial power is not available. The aid is located at 35°25' N, 076°30' W. Select the appropriate lens/lamp combination to meet the operational requirement.

Solution: The operational requirement is for a light that can be detected at a luminous range of 3 nautical miles on 80 percent of the nights. The color of the lens is red, and the contact closure time from Table 5-1 for a Fl 4 (0.4) characteristic is 0.4 seconds. Background lighting is minor; therefore the threshold of illuminance, E, is 6.7 sea-mile candela. Appendix A lists the visibility as 8.0 nm for 90 percent of the nights at the aid's location.

Use Allard's Law (equation 2-7) to calculate the effective luminous intensity:

$$I_e = \frac{E * D^2}{(0.05)^{\frac{D}{V}}},$$

where:

- $E = 6.7$ sea-mile candela for minor background lighting;
- $D = 3$ nm, from the operational requirement; and
- $V = 8.0$ nm from Appendix A.

Solving Allard's Law yields a value of 185 candela for the required effective luminous intensity.

From Chapter 3, all of the standard omnidirectional lanterns are approved for use on multiple-pile structures. Entering Tables 6-1, 6-2, 6-3, and 6-4, using 0.4 seconds for the contact closure time and red for the lens color, it is determined that no lens/lamp combination (using 12V power) will fully meet the stated operational requirement. The waterway manager must decide whether to change the requirement, search for a near fit solution, approve the use of a rotating beacon (VRB-25), or determine that multiple aids must be designed to meet the requirements. In the example given, a review of Table 6-4 indicates the 300mm lantern outfitted with 12V, 3.05A lamp has a tabulated luminous intensity of 180 candela for the given characteristic. The difference from the required intensity of 185 candela is not significant, and this lens/lamp combination may be selected to meet the stated requirement. Each district is given the responsibility to evaluate aid design solutions that do not meet the stated requirements for their effect on safe navigation. In general, a lens/lamp combination which meets or exceeds the luminous intensity requirement should be used whenever possible. However, there is a great deal of uncertainty as to the visibility at any given location for a selected percentage of time, and a large variance in the actual luminous intensity provided by a given lens/lamp combination. Therefore, small differences between tabulated intensities and calculated requirements should not be given undue weight when evaluating aid performance.

Example: A new aid to navigation is to be located along the Maine coast to assist mariners piloting in coastal waters. The aid will be located at 44°55' N, 066°59' W. The desired luminous range is 6 nautical miles for 80 percent of the nights. Background lighting is negligible, and commercial power is available. The characteristic of the light is one white flash every 10 seconds. Identify all optics that meet the operational requirement for luminous range.

Solution: The operational requirement is for a light that can be detected at a luminous range of 6 nautical miles on 80 percent of the nights. Background lighting is negligible; therefore the threshold of illuminance, E, is 0.67 sea mile candelas. Appendix A lists the visibility as 3.3 nm or better for 80 percent of the nights at the aid's location.

Use Allard's Law (equation 2-7) to calculate the effective luminous intensity:

$$I_e = \frac{E * D^2}{(0.05)^{\frac{D}{V}}},$$

where:

- $E = 0.67$ sea-mile candela for no background lighting;
- $D = 6$ nm, from the operational requirement; and
- $V = 3.3$ nm from Appendix A.

Solving Allard's Law yields a value of approximately 5600 candela for the required effective luminous intensity.

A review of Tables 6-1 through 6-4, 7-1, and 7-2 yields the following clear lens/lamp combinations with effective luminous intensities equal to or exceeding 5600 candela, and displaying a single white flash every 10 seconds:

- 300mm lantern outfitted with the 120V, 250 watt lamp, and with a contact closure time of 2 seconds or more;
- VRB-25 rotating beacon, with any 12-volt lamp, rotating at one (1) rpm; and
- DCB-24 rotating beacon, with the 120V, 1000 watt lamp, rotating at six (6) rpm.

The choice of the "best" optic to select will depend on a number of factors. Because commercial power is available, the 300mm lantern, outfitted with 120V, 250 watt lamps, and with a contact closure time of 2 seconds (20-percent duty cycle) will provide an adequate signal. This will require ordering a "special characteristic" flasher from a qualified vendor. If, however, the location of the aid was in a remote area, the VRB-25 rotating beacon, outfitted with 12V, 0.77A lamps, and rotating at one (1) rpm would best meet the operational requirements. A cost/benefit analysis would be the preferred way to decide between competing engineering options.

4. Selecting an Optic for a Major Aid.

Example: The current optic at Farallon Light, off the California coast, provides a light with a luminous range of 9 nautical miles for 90 percent of the nights. The characteristic is one white flash every 15 seconds. It is mounted at a height-of-eye of 358 feet. The new operational requirement is for a light with a luminous range of 10 nautical miles that is available 90 percent of the nights. The characteristic is to remain one white flash every 15 seconds. Identify optics that will provide the required signal.

Solution: The operational requirement is for a light visible at a luminous range of 10 nautical miles for 90 percent of the nights. Use the general value of 15 feet for the height of eye of the observer. The desired characteristic of the light is one white flash every 15 seconds. The aid is located at 37°41.9' N and 123°00.1' W. Background lighting is negligible; therefore, the threshold of illuminance, E, is 0.67 sea-mile candela. Appendix A lists a visibility of 3.2 nm or better for 90 percent of the nights at the aid's location.

The first step is to calculate the geographic range using equation 2-8:

$$\text{Geographic Range} = 1.17 * \left(\sqrt{h_1} + \sqrt{h_2}\right)$$

where:

- h_1 = 358 feet, for the height of the light above mean sea-level; and
- h_2 = 15 feet, for the height-or-eye of the principle users.

The geographic range is almost 27 nautical miles (placing the light on top of a cliff certainly helps!). Because the geographic range exceeds the operational requirement, the light may be detected at the stated operational range provided optics and characteristics can meet the required luminous intensity.

Next, use Allard's Law (equation 2-7) to calculate the effective luminous intensity:

$$I_e = \frac{E * D^2}{(0.05)^{\frac{D}{V}}},$$

where:

- $E = 0.67$ sea-mile candela for no background lighting;
- $D = 10$ nm, from the operational requirement; and
- $V = 3.2$ nm from Appendix A.

Solving Allard's Law yields a value of approximately 780,000 candela for the required effective luminous intensity. The optics in Tables 7-1 and 7-2 that are capable of providing intensities greater than 780,000 candela are the DCB 24 or DCB 224 beacons rotating at one (1) or two (2) rpm..

The DCB 224 beacon, rotating at 2 rpm has an effective luminous intensity of 860,000 candela (as listed in Table 7-1). The characteristic of this optic is one white flash every 15 seconds (2 flashes/revolution x 2 revolutions/minute x 1 minute/60 seconds). The desired characteristic of one flash every 15 seconds *and* a luminous range of 10 nautical miles is possible with this combination.

Example: Vessels traveling northward along the southern Florida coast typically follow the Gulf Stream to take advantage of a favorable current. To provide a visual check on their position, a series of lighthouses have been built along the coast. One of these lights, Sand Key Light, is located about 7 miles off the coast of Key West, Florida at position 24°27.2' N 081°52.6' W. Select a light that can be detected at a luminous range of 15 nautical miles for 90 percent of the nights. Vessels needing to use the light have an average height-of-eye of 30 feet above sea level. The optic will be enclosed, with clear lantern panes, at a height of 90 feet above mean sea level. Commercial power is not available.

Solution: The operational requirement is for a light with a luminous range of 15 nautical miles on 90 percent of the nights. The characteristic is not specified. Appendix A lists the visibility for 90 percent of the nights at the aid's location as 9.8 nm. Background lighting is none; therefore, the threshold of illuminance, E, equals 0.67 sea-mile candela.

First, calculate the geographic range of the light using equation 2-8:

$$\text{Geographic Range} = 1.17 * \left(\sqrt{h_1} + \sqrt{h_2}\right)$$

where:

- h_1 = 90 feet, for the height of the light above mean sea-level; and
- h_2 = 30 feet, for the height-or-eye of the principle users.

The geographic range is 17.5 nautical miles. Because the geographic range exceeds the luminous range, the light may be detected at the required distance.

Next, use Allard's Law (equation 2-7) to calculate the effective luminous intensity:

$$I_e = \frac{E * D^2}{(0.05)^{\frac{D}{V}}},$$

where:

- E = 0.67 sea-mile candela for no background lighting;
- D = 15 nm, from the operational requirement; and
- V = 9.8 nm from Appendix A.

Solving Allard's Law yields a value of 14,800 candela for the required effective luminous intensity of the signal. As the optic will be enclosed with clear lantern panes, divide the necessary intensity, 14,800, by 0.88, to determine the required effective luminous intensity of the optic. This results in a value of 16,800 candela for the required effective luminous intensity of the optic.

Because commercial power is not available, the DCB 24 and DCB 224 rotating beacons cannot be used. Table 7-2 provides several combinations of the VRB-25 with 12-volt lamps and various rotation rates which will meet the operational requirement. Before final selection of the lighting hardware, the waterways manager should consider all the aspects of the system to be installed. While a VRB-25 outfitted with a 12V 35W tungsten-halogen lamp and clear lenses, rotating at one (1) rpm, provides significantly more light output (77,000 candela) than this example requires, it may still be the optimum choice since (1) solar power is relatively abundant at this latitude, and (2) the tungsten-halogen lamps are rated for 2000 hours of life, versus 500 hours for the standard 12-volt marine signal lamps (see Table 5-2).

APPENDIX C. CALCULATIONS FOR PERFORMANCE EVALUATION OF EXISTING OPTICAL SYSTEMS

The procedures outlined in Chapter 3 may be used to evaluate the optical performance of existing lights as well as for selecting the appropriate lens/lamp combinations for new aids to navigation. To start, list the known information about the signal. Use Appendix A to determine the local visibility at the aid location for the appropriate percent of nights. The tables in Chapters 6 and 7 provide the effective luminous intensities of standard omnidirectional lanterns and rotating beacons, broken down by lens color, lamp rating, and contact closure time or rotation rate. Tables are also provided for classical (assembled) lenses (both omnidirectional and for fresnel flash panels). Calculate the luminous range of the optic by using Allard's Law, and compare this with the operational requirement. Do not forget to apply lantern pane corrections, when necessary. The geographical range of major aids should also be calculated to determine the adequacy of the height of the signal. For range applications, use the Range Design Program, described in COMDTINST M16500.4(series), "Range Design Manual," to evaluate the performance of range lights. Chapter 8 provides data tables for standard range lanterns and, due to the large number still in service, the FA-240 range lantern.

Below are some simple examples for (1) determining the luminous intensity of a given lens/lamp combination, (2) evaluating the performance of a buoy light, (3) evaluating the performance of a fixed, minor aid to navigation, and (4) evaluating the performance of a major aid to navigation.

1. Determining the Luminous Intensities of Lighted Aids to Navigation.

Example: What is the effective luminous intensity of a 250mm lantern with 12V 2.03A lamps, displaying a FL W 4 (0.4) characteristic?

Solution: Table 5-1 lists the contact closure time for a Fl 4(0.4) characteristic as 0.4 seconds. Enter Table 6-3 (Effective Luminous Intensities—250mm Lantern) with a contact closure time of 0.4 seconds and a lens/lamp combination of 12V 2.03A lamp with a clear lens. The effective luminous intensity is 390 candela.

Example: A DCB24 is equipped with a 120V 1000W lamp and is rotated at five rpm. The optic is installed in a lighthouse tower to protect it from the environment. What are the effective luminous intensities to use to calculate the luminous ranges for a white, red, and green signal?

Solution: Enter Table 7-1 (Effective Luminous Intensities—DCB24 and DCB224 Beacons) for a DCB24 optic rotating at five rpm (Note: The only authorized lamp for the DCB24 and DCB224 Beacons is the 120V 1000W tungsten-halogen lamp). The effective luminous intensities are 510,000 candela for white light, 110,000 candela for red light, and 100,000 candela for green light. Because the optic is housed in a protective enclosure, these intensities must be multiplied by a "lantern pane" correction factor of 0.88. The resulting intensities used to calculate effective luminous range are 450,000 candela for white light, 97,000 candela for red light, and 88,000 candela for green light. (Note: Round intensities to two significant figures.)

2. Evaluating Performance of a Buoy Light.

Example: Consider a lighted buoy located off the southern California coast, in approximate position 33°26.9' N 118°29.6' W, with a 155mm lantern and 12V 0.77A lamps. Background lighting is minor, and the desired availability is 80 percent. The flash characteristic is one green flash every four seconds (Fl G 4(0.4)). The desired operational range is 4 nautical miles. Does the buoy meet the operational requirement?

Solution: Table 5-1 lists the contact closure time for a Fl 4 (0.4) characteristic as 0.4 seconds. From Table 6-1 (Effective Luminous Intensities—155mm Lantern), the effective luminous intensity for the 0.77A lamp, with a green lens and a 0.4 second contact closure time, is 40 candela.

Appendix A lists the visibility for the one degree grid about 33° N 117° W as 5.4 nm for 80 percent of the nights.

Use Allard's Law (equation 2-7) to calculate the luminous range of the buoy light:

$$I_e = \frac{E * D^2}{(0.05)^{\frac{D}{V}}},$$

where:

- $E = 6.7$ sea-mile candela for minor background lighting,
- $V = 5.4$ nm from Appendix A, and
- $I_e = 40$ candela from Table 6-1.

Solving for D cannot be done directly. The solution requires an iterative process, where an estimated value for D is used in the equation. If the resultant value is greater than the effective intensity, a smaller value for D is tried. If the resultant value is smaller, a larger value of D is tried. The process is continued, until the results of the equation equal the known value of the effective intensity. In this example, the luminous range for 80 percent of the nights provided by the signal is 1.6 nautical miles. This is less than the stated operational range of 4 nautical miles. Therefore, the buoy does not meet the operational requirement of providing a luminous range of 4 nautical miles for 80 percent of the nights. Either the operational requirement will need to be reevaluated or a larger size lamp will need to be installed to increase the effective luminous intensity of the optic. (Note: In this example, the effective luminous intensity necessary to meet the stated operational requirement is approximately 1,000 candela. Thus, an operational requirement of providing a 4 nautical mile luminous range, against minor background lighting, for 80 percent of the nights, cannot be achieved with the 155mm buoy lantern.)

3. Evaluating Performance of a Fixed Minor Aid to Navigation.

Example: On the Columbia River, at approximate position 46°10.2' N, 124°05.6' W, a vented 250mm lantern is equipped with a 12V 3.05A lamp. The characteristic is a white group flash; with two flasher every six seconds (Fl (2) W 6). Background lighting is negligible. What is the luminous range of the light for 80 percent of the nights?

Solution: Table 5-1 lists the contact closure time for a Fl (2)6 characteristic as 1.0 second. Table 6-3 (Effective Luminous Intensities—250mm Lantern) lists the effective luminous intensity, using a 3.05A lamp and a clear lens, as 810 candela. Appendix A lists the visibility for the aid's location as 7.1 nm for 80 percent of the nights.

Use Allard's Law (equation 2-7) to calculate the luminous range:

$$I_e = \frac{E * D^2}{(0.05)^{\frac{D}{V}}},$$

where:

- $E = 0.67$-sea mile candela for no background lighting;
- $V = 7.1$ nm, from Appendix A; and
- $I_e = 810$ candela, from Table 6-3.

Solving for D, the luminous range provided by the signal is 7.4 nautical miles. The aid can be detected at a distance of 7.4 nautical miles, or more, on 80 percent of the nights of the year.

Example: A VRB-25 rotating beacon is installed along the Chicago shore of Lake Michigan, in approximate position 41°52.4' N 87°32.7' W. The beacon is equipped with six clear lenses and a 12V 3.05A lamp, and rotates at two-thirds (2/3) rpm. Background lighting is considerable. The desired availability is 90 percent. Determine the characteristic, the luminous range for 90 percent of nights, and the nominal range of the light.

Solution: Table 7-2a (Effective Luminous Intensities—VRB-25 Rotating Beacon (White)) lists the luminous intensity for the optic as 51,000 candela. The beacon displays six flashes per rotation and rotates at 2/3 rpm. The characteristic is one white flash every 15 seconds (1 revolution/6 flashes x 3 minutes/2 revolution x 60 seconds/minute). (Note: To determine the flash rate, the rotation rate must be inverted to show the number of minutes per revolution.) Background lighting is considerable; therefore, the threshold of illuminance, E, equals 67.0 sea-mile candela. Appendix A lists the visibility for the aid's location as 4.3 nm for 90 percent of the nights.

Use Allard's Law (equation 2-7) to calculate the luminous range:

$$I_e = \frac{E * D^2}{(0.05)^{\frac{D}{V}}},$$

where:

- $E = 67.0$ sea-mile candela for heavy background lighting;
- $V = 4.3$ nm, from Appendix A; and
- $I_e = 51{,}000$ candela, from Table 7-2.

Solving for D, the luminous range is 4.9 nautical miles. This means that the light may be detected at a range of 4.9 nautical miles or greater, against considerable background lighting, on 90 percent of the nights of the year. To determine the nominal range of the light, substitute values of E = 0.67 sea-mile candela, and V = 10 nm in Allard's Law. The resulting nominal range is 18 nautical miles. This example illustrates the importance of understanding the difference between nominal and luminous ranges.

Example: A 300mm lantern, with a red lens, is mounted on a skeleton tower located along the Florida Gulf Coast, in approximate position 29°23.3' N 83°20.4' W. The flash characteristic is one red flash every four seconds (Fl R 4(0.4)). The lantern is equipped with 12V 2.03A lamp. What is the luminous range of the light for 80 percent of the nights?

Solution: Table 5-1 lists the contact closure time for a Fl 4(0.4) characteristic as 0.4 seconds. Table 6-4 (Effective Luminous Intensities—300mm Lantern) lists the effective luminous intensity for the signal as 150 candela. Background lighting is minor; therefore, the threshold of illuminance, E, equals 6.7 sea-mile candela. Appendix A lists the visibility for the aid's location as 10.3 nm for 80 percent of the nights.

Use Allard's Law (equation 2-7) to calculate the effective luminous range:

$$I_e = \frac{E * D^2}{(0.05)^{\frac{D}{V}}},$$

where:

- $E = 6.7$ sea-mile candela for minor background lighting;
- $V = 10.3$ nm, from Appendix A; and
- $I_e = 150$ candela, from Table 6-4.

Solving for D, the luminous range of the signal is 6.1 nautical miles or greater for 80 percent of the nights of the year.

4. Evaluating Performance of Major Aid to Navigation.

Example: Chatam Light, on the Massachusetts coast in approximate position 41°40.3' N 69°57.0' W, is equipped with a DCB224 rotating beacon with 120V 1000W lamps. The light rotates at a speed of six rpm to provide a characteristic of two white flashes every 10 seconds (FL (2) W 10). Background lighting is negligible. The height of the light is 80 feet above mean sea level. A lantern pane correction is required. What is the luminous range of the light for 90 percent of the nights?

Solution: Table 7-1 (Effective Luminous Intensities—DCB24 and DCB224 Beacon) lists the luminous intensity for a DCB224 rotating at six rpm as 450,000 candela. To account for the light energy lost due to the lantern panes, multiply 450,000 by 0.88 to obtain the *effective luminous intensity of the light signal* of 396,000 candela. With negligible background the threshold of illuminance, E, equals 0.67 sea-mile candela. Appendix A does not list a visibility for the aid's location for 90 percent of the nights. **Therefore, a default value of 2 nautical miles should be used for the visibility.**

Use Allard's Law (equation 2-7) to calculate the effective luminous range:

$$I_e = \frac{E * D^2}{(0.05)^{\frac{D}{V}}},$$

where:

- $E = 0.67$ sea-mile candela for no background lighting,
- $V = 2.0$ nm, from Appendix A (default value); and
- $I_e = 450{,}000$ candela (from Table 7-1) * 0.88 = 396,000 candela.

Solving for D, the luminous range of the optic is approximately 6.4 nautical miles for a visibility of 2.0 nautical miles. (Note: For 80 percent of the nights, the visibility is 4.2 nm or greater, resulting in a luminous range of 12 nm, or more, for 80 percent of the nights of the year.)

The geographic range of the light is determined to be 15 nm, using equation 2-8:

$$\text{Geographic Range} = 1.17 * \left(\sqrt{h_1} + \sqrt{h_2}\right)$$

where:

- $h_1 = 80$ feet, height of signal above mean sea leverl; and
- $h_2 = 15$ feet, height of eye of mariner (if no specific user group defined).

Because the geographic range exceeds the luminous range of the light for a visibility of 2.0 nm (and also the luminous range for 80 percent of the nights), the structure height is adequate.

Example: Chesapeake Light, at the entrance to Chesapeake Bay, Virginia, in approximate position 36°54.3' N 75°42.8' W, is equipped with a VRB-25 with 12V 50W lamps, two blanking panels, and four clear lenses. The rotation speed is two rpm, providing a group of two white flashes every 15 seconds. Background lighting is negligible. The height of the light is 117 feet above mean sea level. No lantern pane correction is required. What is the luminous range of the light for 90 percent of the nights?

Solution: Table 7-2a (Effective Luminous Intensities—VRB-25 Rotating Beacon (White)) lists the luminous intensity for the VRB-25 with 12V 50W lamps and clear lenses, and rotating at two rpm as 60,000. The threshold of illuminance, E, for no background lighting is taken to be 0.67 sea-mile candela. Appendix A lists the visibility for the aid's location as 5.1 nm for 90 percent of the nights.

Use Allard's Law (equation 2-7) to calculate the luminous range:

$$I_e = \frac{E * D^2}{(0.05)^{\frac{D}{V}}},$$

where:

- $E =$ 0.67 sea-mile candela for no background lighting;
- $V =$ 5.1 nm, from Appendix A; and
- $I_e =$ 60,000 candela, from Table 7-2a.

Solving for D, the luminous range of the optic is approximately 11 nautical miles or greater for 90 percent of the nights.

The geographic range of the light is determined to be 17 nm, using equation 2-8:

$$\text{Geographic Range} = 1.17 * \left(\sqrt{h_1} + \sqrt{h_2}\right)$$

where:

- $h_1 = 117$ feet, height of signal above mean sea leverl; and
- $h_2 = 15$ feet, height of eye of mariner (if no specific user group defined).

Because the geographic range exceeds the luminous range of the light for 90 percent of the time, the structure height is adequate.

APPENDIX D . CORRECTIONS FOR FLASHED OR ROTATED OPTICS—THE METHOD OF SCHMIDT-CLAUSEN

When using flashed or rotated optics the luminous intensity of the optic must be reduced by some factor to account for the loss of light a viewer can perceive. The U.S. Coast Guard has used a method known as Blondel-Rey-Douglas to correct for flashed or rotated optics. IALA Bulletin 1981/82 examines the Blondel-Rey-Douglas method and the Schmidt-Clausen method. This bulletin reaches the conclusion that each has its own merits; however, the Schmidt-Clausen method is recommended. The U.S. Coast Guard, in accord with the IALA recommendation, intends to begin using the Schmidt-Clausen method. Although actual measurements of luminous intensities must be taken to implement this decision, an explanation of the Schmidt-Clausen method follows.

The variation of instantaneous luminous intensity, I, with time, t, during a flash can be described by the function I(t). This has a maximum value, I_o, which is the peak intensity of the flash. The integrated intensity of the flash, J, is denoted by:

$$J = \int_{\text{flash}} I \, dt . \tag{D-1}$$

Schmidt-Clausen states that the *effective luminous intensity*, I_e, of the flash is given by:

$$I_e = \frac{J}{C + \left(J / I_0 \right)} , \tag{D-2}$$

where C is a visual time constant, taken to be 0.2 seconds for nighttime observation, and I_o is the peak luminous intensity of the light signal. The *Schmidt-Clausen Form Factor*, F, is defined as:

$$F = \frac{\int_{t_1}^{t_2} I(t) dt}{I_0 (t_2 - t_1)} , \tag{D-3}$$

where:

t_1 = the time when flash begins; and
t_2 = the time when the flash ends.

Defining the total duration of the flash, τ, as being the period (t_2 - t_1), equation **(D-2)** can be expressed as:

$$I_e = \frac{I_0 * \tau}{\left(C / F \right) + \tau} . \tag{D-4}$$

The form factor can be determined from a graph of the instantaneous luminous intensity versus time as in Figure D-1. Draw a rectangle with a length equal to the interval $t_2 - t_1$ and of height equal to the peak intensity of the flash. The area A of the rectangle represents the integrated intensity of a steady burning light, while the area A_1 is the integrated intensity of the actual light signal. The form factor is the ratio of the integrated intensity of the light signal to the area of the rectangle.

$$F = {}^{A_1}\!/_{A}\,.$$

The precise choice of the limits t_1 and t_2 is not critical, as long as they occur near zero intensity before and after the flash, respectively. For rotating beams, t_1 and t_2 are usually chosen for times when the luminous intensity is 5 percent of the peak luminous intensity.

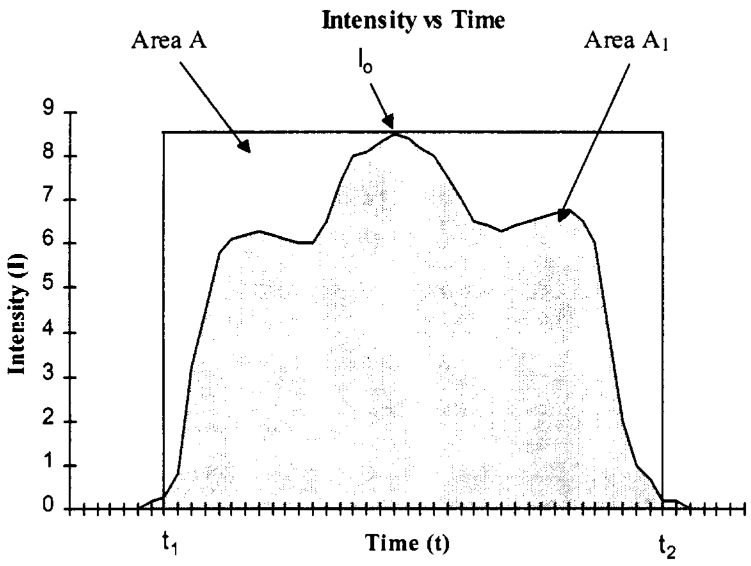

Figure D-1. Example of Luminous Intensity Versus Time

Equation **(D-4)** can be used to calculate the effective luminous intensities of light signals from flashed lamps, such as those used in range lanterns and omnidirectional lanterns. For rotating optics—the DCB24, DCB224, and the VRB-25 rotating beacons—equation **(D-1)** must be converted to an evaluation of the variation of the instantaneous intensity as a function of angular direction. Start with the basic relationship $\theta = \omega\, t$, where ω is the angular velocity of the lens. The form factor can then be written as:

$$F = \frac{\int_{\theta_1}^{\theta_2} I(\theta)\,d\theta}{I_0(\theta_2 - \theta_1)}, \qquad \text{(D-5)}$$

where $I(\theta)$ equals the luminous intensity in a given direction θ, and $\Theta = (\theta_2 - \theta_1)$ is the total angular beam width of the rotating light signal. The limits θ_1 and θ_2 are chosen for directions where the luminous intensity drops to 5 percent of the peak luminous intensity.

The basic relationship, $\theta = \omega\, t$, becomes $\Theta = \omega\, \tau$ when evaluated over the limits θ_1 and θ_2. Substituting the Schmidt-Clausen Form Factor for angular dependence of instantaneous intensity, and the relationship between the beam width and the flash period, equation **(D-4)** becomes:

$$I_e = \frac{I_0 * \Theta}{\omega\left(C/F\right) + \Theta}. \qquad \text{(D-4a)}$$

This equation may be simplified by using the relationship $\omega = 6*R$, where R is the rotation rate of the optic, in rpm. Thus, the effective intensity of a light signal produced by a rotating beacon may be evaluated by:

$$I_e = \frac{I_0 * \Theta}{\frac{C\,(6 * R)}{F} + \Theta}, \qquad \text{(D-6)}$$

where:

- I_0 = peak intensity of the light signal;
- Θ = beam width, in degrees, of the light signal (usually taken between the 5 percent intensity points;
- F = the Schmidt-Clausen Form Factor (using angular dependence of the instantaneous luminous intensity of the light signal);
- R = the rotational speed in rpm of the optic; and
- C = a visual time constant of 0.2 seconds for nighttime observation.

Equation **(D-6)** is used to calculate the effective luminous intensity of all rotating beacons, including the DCB24, DCB224, and VRB-25 rotating beacons, and for rotating classical (assembled) flash panels.

APPENDIX E . GLOSSARY AND ABBREVIATIONS

Allard's Law
A formula relating the illuminance produced on a normal surface at a given distance from a point source of light and the degree of transparency of the atmosphere (assumed to be uniform from source to target). The law may be expressed as

$$E = \frac{\left(I_e * T^D\right)}{D^2} \quad \text{or} \quad E = \frac{\left(I_e * (0.05)^{\frac{D}{V}}\right)}{D^2}$$

where E is the resulting illuminance on the surface, I_e is the effective luminous intensity of the incident light in the direction of measurement, T is the atmospheric transmissivity, V is the meteorological visibility, and D is the distance of the surface (target) to the light source.

Atmospheric Transmissivity (T)
A dimensionless quantity characterizing the transparency of the atmosphere. Transmissivity is the ratio of the luminous intensity of a light source after transmission through a unit length of atmosphere to the luminous intensity of the same light source after transmission through the same unit length in a vacuum.

The unit length for aids to navigation purposes is one nautical mile. A transmissivity value of 0.90 indicates that 10 percent of the light energy is lost because of atmospheric scattering and absorption in traveling one nautical mile.

Availability
The term availability used in this document refers to the percentage of the nights during the year that a mariner would expect to see a lighted aid to navigation at a specified range due to atmospheric conditions. This percentage should be established as the goal of a lighted aid to navigation during the aid design process. The Coast Guard typically uses a value of 90 percent for lighted major aids to navigation and a value of 80 percent for all other lighted aids. Also called "percentage of visibility."

Candela
A candela is defined as one-sixtieth of the luminous intensity of a square centimeter of a blackbody radiator operated at the freezing temperature of platinum, 2046 degrees Kelvin. One candela equals one lumen per steradian.

Color Factor
The fraction of the initial light that is transmitted after it passes through the color filter of the lamp/optic system. For example, a red color factor of 0.28 means that the red light produced by a lamp system after filtering is 28% of the original white light intensity (in photometric units of intensity).

Detection Range	The distance at which an observer first sees (detects) an object. The object may be a ship, land, debris, or an aid to navigation. The detection distance is a function of the brightness of the object, the degree of background lighting, and the local visibility. Luminous and nominal ranges are detection distances calculated by Allard's Law for specific conditions.
Duty Cycle	The duty cycle of an aid-to-navigation light is the total time a lamp is lighted divided by the total period of a flash characteristic, expressed as a percentage.
Effective Luminous Intensity (I_e)	For a flashing light signal there is an apparent reduction in intensity due to the subjective nature of detecting light by the observer. The peak luminous intensity of the light must be multiplied by a correction factor to account for the apparent reduction in intensity. The resulting intensity is called the effective luminous intensity. Appendix D explains how effective luminous intensities are calculated for Coast Guard standard optics using the method of Schmidt-Clausen.
Fan Beam	A fan beam is a concentration of light from a lamp onto the horizontal plane. The angular spread usually covers 360 degrees; however, smaller angles can be used. Flash characteristics are obtained by flashing the lamp. U.S. Coast Guard optics that produce fan beams are the 155mm, 200mm, 250mm, and 300mm lanterns, and classical (assembled) lenses.
Geographic Range	The maximum distance a light can be seen by a given observer, ignoring limitations due to the luminous intensity or visibility. It is a function of the height of the light and the observer's height-of-eye. Assuming a light is bright enough to always be seen, an observer will lose sight of the light when it drops below the horizon (geographic range). The only way to increase the geographic range is to either raise the height of the light or the height of eye of the observer.
Identification Range	The distance at which the mariner can actually identify an object. The identification range of a light depends on numerous variables, including: • Time-dependent buoy motion, vertical divergence, and flash characteristic. • Atmospheric conditions, rain, fog, snow, dust, pollutants, etc. • Obstructions in the optical plane of the light (e.g., mounting hardware). • Manufacturing tolerances of optical components. • Hardware maintenance (e.g., lens/lamp, battery, control systems, etc.). • Background lighting. These variables are probabilistic in nature and may vary with locality and time of the year. Often, the recommendations of local pilots and the experience of district and field personnel are required to judge the effect of these variables on the identification range of a light.

Illuminance (E)	Illuminance is the total luminous flux incident per unit area of a surface. The unit of illuminance used for visual signaling at sea is the sea-mile candela. One sea-mile candela is the luminous flux density of one lumen distributed uniformly over a surface area of one square mile.
Light	Light is defined as energy that is visible to the human eye. Radiated energy with wavelengths between 4000 and 7000 Å is the range of the visible light spectrum. The eye is most responsive to light energy in the yellow-green region of the visible light spectrum (5550 Å). When the term "luminous" precedes a definition for the energy, flux, or intensity of the light, the spectral response of the eye has been accounted for.
Lumen	A lumen is defined as the amount of luminous flux emitted within one steradian from a point source having a uniform luminous intensity of one candela.
Luminance	Luminance is the luminous intensity, per unit area, of a surface projected onto a plane normal to the direction of propagation. Also known as "brightness."
Luminous Flux	Luminous flux is the time-rate flow of energy from a light source that produces a visual effect on the eye. It is measured in units of lumen.
Luminous Intensity (I)	Luminous intensity is the time-rate flow of energy per unit solid angle emitted from a light source. It is measured in units of candela.
Luminous Range (D)	The luminous range is the maximum distance at which a light can be detected for a given condition of visibility. It is a function of three variables: the effective luminous intensity (I_e) of the light, the meteorological visibility (V), and the threshold of illuminance at the eye (E). These variables are related by an equation known as Allard's Law.
Meteorological Optical Range	The distance required for the atmosphere to reduce the contrast of an object against its background to 5 percent of the value the object would have at zero distance. Meteorological optical range is commonly called meteorological visibility or visibility. Visibility and atmospheric transmissivity are related in the following manner: $T^V = 0.05$ or $T = (0.05)^{\frac{1}{V}}$
Nominal Range	The luminous range of a light when calculated with a visibility of 10 nautical miles and a threshold of illuminance of 0.67 sea-mile candela. Nominal ranges are used on charts to advertise the approximate range at which mariners can expect to detect a given light on a clear night. Nominal ranges can differ significantly from luminous ranges, especially in areas that frequently experience limited visibility.

Pencil Beam	A pencil beam is a concentration of light about a single line of direction. Rotating a pencil beam produces a high-intensity omnidirectional flashing light. The Coast Guard standard optics that produce pencil beams are the DCB24, DCB224, and VRB-25 rotating beacons, and the RL24 and RL14 range lanterns. The 250mm lens with condensing panels produces a combination fan beam and pencil beam.
Recognition Range	The distance at which the mariner can state, with a high degree of certainty, the type of object being viewed. For example, a mariner determines that the object is an aid to navigation, but doesn't yet know which aid. The recognition range is primarily a function of the shape and color of the object and the visual acuity of the observer.
Steradian	The steradian is the angular measurement of a cone of lines from the center to the surface of a sphere. A complete sphere has 4π steradians of solid angle. An analogy in two dimensions is a plane angle which is the divergence of two lines from a single point. Where a plane angle is measured in units of radians or degrees between the two lines, a solid angle is measured in units of steradians inside the cone of lines.
Solid Angle	A solid angle is the three-dimensional divergence of a group of lines from a single point. A cone of lines originating from the center of a sphere cuts an area on the surface of the sphere. The solid angle in steradians is equal to the area of the surface cut-out the cone, divided by the square of the radius of the sphere.
Threshold of Illuminance	The threshold of illuminance is the minimum luminous flux density at the eye required to detect a light source against a specified degree of background lighting Threshold of illuminance values used in the Coast Guard are: • 0.67 sea-mile candela for no background lighting; • 6.7 sea-mile candela for minor background lighting; and • 67.0 sea-mile candela for considerable background lighting.
Transmissivity	See Atmospheric Transmissivity.
Visibility	The property of the atmosphere which determines the ability of an observer to see and identify prominent objects by day, or lights or lighted objects by night. A measure of this property of the atmosphere is expressed in units of distance, usually nautical miles. The term is commonly used for "meteorological visibility."

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